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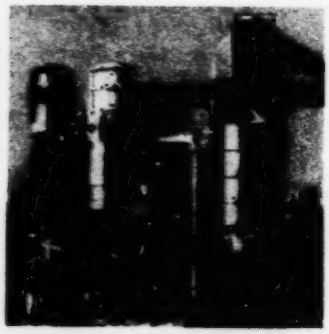
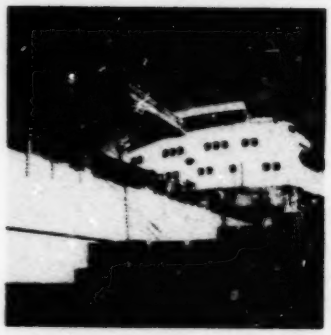
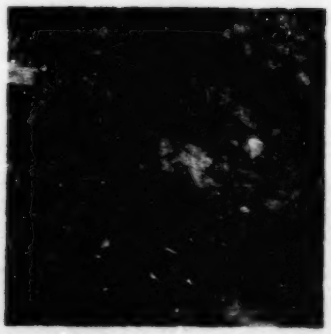


Possibilities and Problems in Manitoba





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WESTERN LABORATORY

The Western Laboratory, located at Vancouver, British Columbia, Canada, was formerly known as the Western Forest Products Laboratory, a branch of the Canadian Forestry Service, Environment Canada until April, 1979.

Effective April 1, 1979 the Laboratory became a research division of Forintek Canada Corp., a Canadian non-profit corporation.

The Laboratory has a staff of 110 actively engaged in work in a dozen scientific and technical disciplines. It is a problem-oriented organization that offers assistance and expert advice to the forest products industry, professional associations and consultants, provincial and federal government agencies, trade associations, equipment manufacturers, educational institutions and the general public. These services are offered with the objective of realizing the optimum benefit to Canadian society from one of the country's most important natural resources — its forests. The general area of responsibility of the Western Laboratory includes the four western Canadian provinces, the Yukon and Northwest Territories.

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PROCEEDINGS

Winnipeg, Manitoba

September 28 to 30, 1977

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Aspen

J.A. McIntosh

Aspen has a lot of good properties but at this point in time, it hasn't got much going for it in western Canada, except its volume – there's a lot of it. It's the most talked about and written about species in the country, but remains the least used. Of course, there are some benefits to the talking and writing; it keeps a lot of scientists and researchers busy examining and writing about aspen. This, of course, is good for the pulp industry. I'm sure one pulp mill could be kept busy just preparing the paper that goes into all these reports. As an example, if you look at the reports from the lab on that table, about half of them are on aspen. It's also good for the transportation and service industries when you look at the continuous round of seminars and talks on aspen. Air Canada, etc.,do all right on these, as well as the hotels. However, it doesn't add much to the provincial coffers or to the financial statement if you don't manufacture anything from aspen.

In the discussion today, I would like to deal with aspen on a broad basis and then look at Manitoba in particular.

Aspen has excellent texture. It's a medium-density, light-coloured wood. It is particularly well suited for such things as particleboard, excelsior, plywood core stock, pallets and furniture. It has been very successfully manufactured into a number of products in Europe and in North America, primarily the Lake States region. With all these good things about aspen, why aren't we using more?

In western Canada where aspen is one of our most abundant species, there are two broad reasons for this. Firstly, you might call them technical difficulties. These are the result of the basic nature of the raw material – the characteristics of the logs and trees and the properties of the wood itself. These add up to a great deal of added costs in processing aspen. Secondly, there are the market and economic problems, which depend on the particular product you might have in mind. In many cases, there are higher processing costs with aspen and these relate back to the technical characteristics of the trees and logs. You have lower product prices and obviously then, lower financial returns to any potential manufacturer in comparison to the returns from manufacturing material from coniferous species. In other cases, much of the industry that could use poplar successfully is not located close to the aspen resource. You have the aspen resources here. The major markets are hundreds of miles away. Many of the products that poplar is well suited for have very limited Canadian markets.

Let's look then at some of the possible uses for aspen and some of the problems that you run into, e.g. lumber. Here an aspen producer will run into a very large number of technological difficulties. In the raw material, i.e. logs and trees, there is a very high cull factor. Of course, this is going to result in a higher logging cost. There is alot of crook and sweep in the trees, primarily in the top logs. With crook and sweep in the logs, of course, you don't get the lumber recovery factor that you get from straight logs. And by recovery factor, I mean the volume of lumber output for the volume of wood input into a mill. Obviously, these defects reduce the production rates in the mill. Also you may only have half or 3/4 of the stand that you can use, thus increasing the costs. Then you have to dry the lumber. We mentioned in the audio-

visual program that the lab is working on poplar lumber kiln drying schedules. They may be good and produce a reasonably good product, but the kiln time is possibly twice as long as for your conventional softwoods, which results in about a 50% increase in your drying costs. Then you have the drying degrades. The main cause of degrade is crook and despite the drying schedule much of the output will be degraded for this reason. You saw samples of crook this morning – the crooked stud. No builder is going to use a stud with a great sweep in it. Another problem with aspen is fuzzy grain: even with sanding you don't get rid of it. Here's a piece of aspen core stock. Two pieces nice and smooth – the third piece has been sanded and resanded and the fuzzy grain is still there. When you do get your aspen out in the form of lumber, you have to get into the market place. It can be graded at the present time as northern aspen which has acceptable strength characteristics for the construction market. But you have the problem of getting a new species accepted. The builders are not used to it and you have a problem getting into the market place. You have to come in at a lower price. Again, a negative factor as far as a producer is concerned. Well, with all these things against aspen, how have they made use of it in the Lake States region?

Well, first of all, they have a very strong pulp industry, and roughly half of the pulpwood consumed in Minnesota, for instance, is aspen. This includes material going into such things as fibreboard and particleboard, as well as into the pulp mills for paper production. This not only provides the sawmills with an outlet for chips, but also provides a market for the logs that aren't suitable for lumber manufacture. Also there is a better market for the low-grade material that might come from the sawmills. As a matter of interest, in that area, I understand the minimum diameter of an aspen sawlog is something around 8".

Then you get into the market situation in the Lake States region. The major market for aspen lumber is the pallet and container manufacturers. You have to realize a couple of things about these markets. The pallet producers produce a relatively low-cost product and they traditionally use the lowest cost materials that are available to do the job, such as low grades and shorts. Secondly, you have a proximity to the major industrial and population centres. The pallet manufacturers are adjacent to the users and therefore don't have a high transportation cost. If you look at the situation in Manitoba, although you have a small pallet market in Winnipeg, the main market would be in the East, but because of transportation costs it is not an attractive market area.

Another traditional market for aspen lumber is core stock. In this case, the aspen is edge-glued. This is an example of core stock material. There are three pieces edge-glued together to provide a base for overlayed veneers and laminates, such as go into desks and possibly wall panels. But the particleboards are rapidly replacing lumber core stock. Particleboard is easier to obtain, cheaper to use and as better quality particleboards are coming on the market, the opportunity for the aspen core board is decreasing.

Another opportunity in the Lake States area is the furniture markets. Aspen is used both in exposed and hidden parts of furniture. This is generally the lower priced furniture line such as unfinished furniture, etc. If you have low priced furniture, then you probably use low priced lumber.

Another factor you must consider when looking at the lumber situation is the distribution of grades obtained. The furniture industry is primarily concerned with the higher grades, which in aspen are the 2A common or better grades. The recovery of these grades would be something like 45% of the lumber obtained from good logs. What do you do with the other 55%? In the Lake States region this can go to the pallet and container markets or as pulpwood, but here in western Canada, what do you do with it? A similar situation exists in B.C. with alder and maple. There's a good market for the higher grades in the furniture industry in California, but the problem is the disposal of the low grade material. As a result few operators survive for long. So in looking at the provincial aspen situation, the lumber produced will largely have to go to a different market than that in the Lake States, but where do we get these markets in western Canada? What might we produce? There has been a lot of work on aspen at the lab in Van-

couver over the past six years, and dimension lumber would seem to be the more promising opportunity. However, you might say that doesn't sound very encouraging when the first major aspen stud mill in Canada went broke a few years ago in Alberta. In this particular situation, it may have been more to do with the way the studs were produced than the quality of the product.

As far as the production of dimension lumber is concerned, there are advantages. It would be graded as northern aspen under the N.L.G.A. rules for dimension lumber. This is a strength grade rather than an appearance grade as are the N.L.H.A. grades for factory lumber. It would therefore include defects, such as knots and other defects which cause fall down to the lower grades in the factory lumber. This fall down could be as high as 50 – 60% in factory lumber and you have a disposal problem as well as a problem in marketing. What do you do with the low-grade material? If it goes as dimension, most would actually end up as a suitable product. One of the studies by the lab was on a sample of selected balsam and poplar. The recoveries were 80% standard or No. 2 and better construction lumber, which is comparable to the grade recoveries from coniferous or softwood species. In the studies, part of the samples were graded under the N.L.G.A. and part under the N.L.H.A. rules. The studies showed that only the higher quality large logs were suitable for any kind of recovery of factory lumber. That wasn't the case with the dimension grades. One of the studies was carried out in Manitoba. This sample included randomly selected trees, which were cut into 8-foot blocks to a 5-inch top diameter. They were sawn into 2 x 3's and 2 x 4's. The recovery here was 84% No. 2 and better. One problem with aspen in Manitoba is the small tree size. I understand the majority of trees are under 10 inches d.b.h. which of course results in increased logging and milling costs.

Now let's look at the situation here in Manitoba, as I see it. My information has stemmed from various sources, most of which are at least three years old, so the information may not be up to date, but please correct me if I am wrong.

Here you have four species of poplar, only two of which can be considered important as far as wood production is concerned. These are the trembling aspen and the balsam poplar. Of these two, trembling aspen is more abundant, about seven times that of balsam poplar. Of the net merchantable volumes available, there is some 32MM cunits (a cunit is 100 cu. ft.) and of this, 28MM is aspen. This volume is about 23% of the total growing stock, both coniferous and deciduous, in the province – a sizable volume of material. This volume is concentrated in two areas – the southeastern and western portions of the province. This concentration, of course, has an advantage as far as utilization is concerned. I understand that at the present time about 12% of the annual allowable cut of aspen is harvested and in terms of lumber, this could be about 12MM fbm.

Where does this cut go? If we go back to the early days, aspen was cut for building construction and rough siding for the settlers, as lumber for a number of uses and also for pulpwood and fuelwood. I understand that at one time there was a relatively large volume of match splints produced in the southeastern corner of the province.

During the late '50s and early '60s, the major products produced were rough and dressed lumber for furniture components, grain doors, pallet stock, fish boxes, plywood, pulpwood and fuelwood. Coming further to the late '60s and early '70s, more complete utilization of the poplar stands began to occur, primarily I presume because of government regulations. The particleboard plant at Sprague was built and there was an increasing demand for poplar from the North Central states. The particleboard plant is, of course gone which has seriously reduced utilization in the southeastern part of the province. The concentration of the cut at this time is in Region 1, the mountain area, or the Duck Mountain, Swan River area. I understand that the major aspen producers there are cutting up to 5MM fbm a head and the chips are being sold to the pulp mill at Fort Frances. Two-thirds of the aspen lumber produced is apparently sold rough and for the most part goes to supply local needs such as grain doors, containers, pallets, furniture stock and crating. I understand that some of the pallet stock and some of the crating material is exported, but for the most part it is

used by plants in the Winnipeg area.

Now let's look at the future possibilities of aspen. You have two pulp mills in the province at Pine Falls and The Pas. These will not use aspen as long as there is an adequate supply of softwoods available, so there is not much opportunity as far as pulp manufacture is concerned. There is a possibility of a waferboard plant such as the Aspenite plant in Saskatchewan. A waferboard plant requires some 80,000 cunits per year for a viable operation and the only region where this volume of wood would be available on a continuous basis is the western region and that's where your major lumber (aspen) producers are established. The question then becomes, is there sufficient wood to support both? The present lumber market could have an indirect benefit on the aspen situation. I understand that the local lumber yards would welcome aspen if they could get it. Certainly, as the price of softwood goes up, the opportunity of getting something cheaper that is going to do the job exists. At the present time, possibly there would be an opportunity there. But if you build a plant to produce northern aspen dimension lumber for the present market, you could get into a little risky situation. By the time you establish a position as far as a quota, etc., is concerned, build the plant with the necessary kilns (you have to get into steam kilns to get the proper drying), and develop your sales outlets, there's a possibility that the market may have softened. Traditionally, in North America the market goes up and down depending on the U.S. housing program. Right now it's up. Tomorrow it might go down. Another problem here in Manitoba, of course, is that approximately 78% of the available aspen is under nine inches dbh., and this is small material for a sawmill operation.

So, in conclusion, for the short-term at least, I wouldn't expect a major increase in the use of aspen in Manitoba. I think there will be a gradual expansion in aspen use as the readily available softwoods are exploited and the price of these go up. There is always the possibility that some ingenious entrepreneur could come along with a totally new aspen product. I understand that in Saskatchewan, there is a plant going in to build log cabins from aspen. There is an operator in B.C., who for the past several years has been building log cabins and motels from aspen along the Alaska highway. One of his major problems is obtaining suitable aspen and as a result he now uses pine and spruce. This, then, is the way I see aspen in Manitoba.

Answers to questions.

Problems pulp mills would have if they move into aspen:

In our lab (WFPL) we have examined the kraft pulping of mixtures of poplar with softwoods using up to 20% by weight of poplar. The major processing characteristics were evaluated with particular emphasis on pulp yield and pulp strength. From a technical viewpoint there are several advantages in pulping hardwood/softwood mixtures using the softwood cooking conditions. Full details can be found in the following publications which are available on request from the lab in Vancouver:

Hatton, J.V. Kraft and mechanical pulps from poplar. *In* Poplar Utilization Symposium (Ed. R.W. Neilson and C.F. McBride). Dep. Env., Can. For. Serv., Western Forest Products Laboratory Inform. Rep. VP-X-127, Vancouver, B.C. pp. 155-170, 1974.

Hunt, K. and Hatton, J.V. Increased pulp production by use of hardwoods in softwood kraft mills. Pulp Pap. Can. 77(12): T271-T274 (1976).

Present situation in Manitoba:

L. Johnson

The department has been looking at other uses of aspen, in some cases, uses that would involve very small volumes, such as the production of aspen tongue and groove planking which can be used for interior decorative walls in houses and offices. We are also thinking of looking at the production of aspen shakes and shingles for interior use and possibly for exterior use. To this end we will be working with the lab in integrating a test of aspen shakes and shingles with the red cedar test that was described this morning. I don't know that the pallet industry here is large enough to justify additional pallet capacity in Manitoba. In terms of

large-scale utilization, there has been some discussion of additional capacity or new capacity in the area of waferboard or particleboard in general. That's just being discussed at the moment. Certainly, the problems of small-diameter aspen are there and have to be considered and when one looks at waferboard, one often has to consider the market. If Manitoba were to produce for its own market then the scale of the waferboard plant would be considerably smaller than most that are currently in operation. If, on the other hand, Manitoba were to produce waferboard for the international market, then we have some transportation difficulties to overcome. So in summary, I would say that there is more attention being given in the department to this than before. I don't know that the answers are going to be much better, but with the relatively large volumes of aspen and the relatively high unemployment rates in the whole country, and in Manitoba, that we have seen for the past few years, I would think that there will be more attention given to this underutilized resource in future.

Re: Utilization of poplar in pulp mill

We are finding in our company right now that we are having problems trying to get them to utilize our pine and spruce. The pulp mills are asking us first of all to separate them. There's no great problem. But the thing is they were leaving pine and spruce rotting in the bush because they cannot take the quantities I know other companies in Manitoba are producing right now, so how can we start utilizing the poplar if they are not going to utilize the spruce and pine?

One of the reasons, of course, is the soft pulpwood market at the present time. Most of the pulp mills in our area are cutting back in their production.

Comments on lumber manufacture

One of our mills attempted to manufacture poplar lumber and grade it under the N.L.G.A. rules. They found that because of the cull factor it was practically prohibitive. They couldn't make up the grade, plus the fact of the drying, so the matter of using aspen as an alternate to softwoods at the present time doesn't work.

Bark Utilization

M.N. Carroll

From several points of view, bark is the most worthless part of the tree. If we wish to make some kind of a structural product like particleboard from it, we are faced with the fact that bark itself (unlike wood) does not have any inherent strength. If we wish to include it in particleboard as part of the makeup, we are deterred, if nothing else, by the dirt that goes with the bark. If we want to burn it, we find that it is generally very wet and has a high ash content (again from the dirt), often as high as 15 to 20%. If we want to use it for soil improvement, we find that it decomposes slowly and requires nitrogen to assist in the decomposition.

On the positive side, there are some limited uses. One of these is in wet-process hardboard. By washing the logs, a hardboard plant can use all the bark that goes with the tree. Some mills even use extra bark, with one mill in Sweden using as high as 50% bark in their hardboard. Abitibi uses extra bark in its hardboard operation, but this does not come from washed logs, and the bark itself has to be washed before use. This is done using riffle-boxes similar to those used to separate gold from crushed ore.

Another major use of bark is as a fuel. Pulp mills burn bark for process energy, and bark forms the major component of hog fuel. This use is at present limited to fairly large scale operations such as pulp mills, since the cost of buying and operating small-scale wood-burning equipment is disproportionately high; that is, the capital and operating costs are scale sensitive. On the west coast of B.C., hog fuel is almost completely utilized for process energy. In the interior of B.C., only a small part is so used. The difference is because on the coast the hog fuel can be hauled inexpensively by barge, and the alternative fuel source is fuel oil. In the interior, the cost of overland transport is prohibitive, and the alternative fuel is relatively low-cost natural gas.

The fuel value of bark is low. Inherently it has a potential heat value of about 9000 Btu per pound of dry bark. But bark is half water (at least) and may have 10% dirt in it, so that the potential value is more like 4000 Btu per pound of bark plus water plus dirt. This heat is reduced still more by the fact that some of this available heat in the bark has to be used to evaporate the water. Compared to fuel oil at 16000 to 19000 Btu per pound, or even bituminous coal at 8000 Btu per pound, bark is low efficiency fuel. This comparison suggests that bark will never find a widespread use as fuel, since petroleum fuels and coal can be transported more efficiently.

The particularly undesirable feature about bark as a fuel is the high and variable moisture content. This feature makes it difficult to burn bark cleanly. To obtain a clean burning fuel, the bark has to be reduced to a uniform moisture content. In Vancouver, B.C. a large sawmill does this (to hog fuel actually) by predrying the hog fuel to an average mc of about 35%, using part of it to feed two Energex burners to supply the heat for drying. The dried fuel is then carefully blended to even out any remaining variability in moisture content, and finally it goes to the sawmill boiler. The total cost of this installation is approximately 1 million dollars, including bag houses to catch the fines and fly ash from the drying operation.

The alternative to this is one used by pulp mills, where some form of petroleum fuel is used as "overfire" fuel. If a slug of wet bark hits the furnace, it drops the flame temperature and a smoky fire results. To correct for this, petroleum fuel is metered in an amount to bring the flame temperature back up to the temperature at which clean burning is maintained.

This is the same sort of problem that goes with burning wood in fireplaces or space heaters, the latter of which are now being advertised as alternatives to burning natural gas or fuel oil for house heating. Incomplete combustion leads to a smoky fire that deposits creosote in the chimneys and pollutes the neighborhood. Strangely enough, none of the wood-burning stove designs being advertised today incorporate any provision for using natural gas or LPG as overfire fuel.

The subject of home heating brings up the matter of fuel logs, which are now made by compressing and extruding dry planer shavings in a die to produce a dense firelog. Could these be made from bark? Again the idea is clouded by three things: the firelog process needs dry material (10% mc); the metal dies that are used in the extruders do not take kindly to the dirt in the bark; and the resulting log is not very strong to resist handling. The literature on bark indicates that about half bark and half planer shavings can be used, provided the bark is dry and dirt free.

Another area which is discussed thoroughly in the bark literature is the agricultural uses. These are of two sorts: soil improvers, and ground cover. As a soil improver, bark is a poor choice, as already mentioned. As ground cover, its purpose is both functional and decorative. The functional part is to cover newly planted soil to prevent wind erosion and to control weeds. The decorative part is to provide an architectural effect in landscaping. For this latter purpose, redwood bark from California is shipped all over North America. However, the bark for this must be in a specific form called "nuggets". These are made by hammermilling the bark and screening out a coarse fraction consisting of thick pieces about two inches long. Only this fraction has any value, and redwood is the preferred species because of its red color. Also, it appears that only the corky barks like redwood and Douglas-fir will break up properly into nuggets: the stringy bark will not.

Another subject of great interest today is the possibility of extracting tannins from bark for use as adhesives to replace phenol-formaldehyde glues in plywood and waferboard. In perspective, this is not a means of utilizing bark as such, but of utilizing a small fraction of the bark. Recent studies at the Western Forest Products Laboratory have shown that, while a substantial amount of tannin-like material (15%) can be extracted from hemlock bark, only about a third of this is capable of reacting with formaldehyde to form waterproof resins.

Broadly speaking, although many things can be done with bark, they can in most cases be better doen with wood residue itself (sawdust and planer shavings). While these are available, bark will be regarded more as something for disposal rather than something that has an opportunity for conversion into useful products that are competitive in the market place. The four references given at the end of this paper provide a broad picture of the many things that can be done with bark. None of these suggest any potential for widespread utilization of bark in the sense of the uses that the other wood residues have found in particleboard and pulp, either now or in the future.

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Energy from Wood

J. Dobie

We have only recently become involved in energy from wood residues. My knowledge of it is quite limited.

The subject is "self-sufficiency in energy from manufacturing residues". I intend to go through the potential energy obtainable from the manufacturing residues and show what they're worth and give some indication of the general economics associated with using manufacturing residues for energy purposes.

The initial residue which we get from manufacturing is bark. Bark recovery factors vary and if we use published estimates of measurements of bark thicknesses, these are the kind of volumes we get (Table 1), cubic feet per cunit of wood. Depending on species, it varies from about 11 cubic feet per cunit for lodgepole pine and up to around 28 for Douglas-fir. The relevant species in this part of the country are lodgepole pine or jack pine and spruce. We lose some proportion of bark in transit and these are the reduction factors (Table 1) — 30%, 20%, etc. We also have to make a reduction for bark voids and fissures, giving us reduction factors anywhere from 30% to 10%. What we finish up with at the sawmill or the plant is anywhere from 8 to 14 cubic feet of bark per cunit of wood.

The amounts of residues which are recovered in manufacturing also vary depending on sawmill type. This is an example of two types of sawmills — band headrig and a chipper headrig (Table 2). It shows a variable amount for different types of residues. For the chipper headrig, we get about 43% chips and 6% sawdust. In the band headrig, we get 31% chips and 12% sawdust. In the band headrig, we usually get more lumber — 44% as opposed to 39% in the chipper headrig. If we take as our residues bark, sawdust and planer shavings, assume the pulp chips are going to the pulp mill, what we have left is hogged fuel. This works out to about .75 cubic feet per cubic foot of product in the band headrig and about .67 cubic feet per cubic foot of lumber in the chipper headrig.

If we look at plywood and shingle manufacture, these are the estimates (Table 3): 49% plywood, 47% shingles and 9% lumber in the plywood plant. What this works out to is about .43 cubic feet of hogged fuel per cubic foot of plywood and about .83 cubic feet of hogged fuel per cubic foot of shingle. So what? Well, depending upon how much residue we recover and what the moisture is, this determines the amount of Btus we have available in the residues. This chart indicates that the more residue we recover per unit of output, and the drier it is, the greater is the Btu potential of the residue (Figure 1).

Take, for example, a sawmill which dries lumber. If the lumber is about 42% moisture content and I'm talking about original weight basis, and we want to dry down to about 15% original weight, we need about 35,000 Btus to dry that cubic foot of lumber. This bulls-eye (Figure 1) indicates the number of Btus we have available from dried planer shavings and what it indicates is that any mill which dries lumber and dresses it, has enough potential Btus in the planer shavings to dry the lumber it manufactures, so that the sawmill under these circumstances could be self-sufficient in fuel from the planer shavings alone.

We spoke about the chipper headrig and the band headrig and we indicated the volume of residue available in both of those plants was between .6 and .8 cubic feet per cubic foot of product. This indicates that for most circumstances, sawmills would have a surplus of Btus available anywhere above the dotted lines of Btu requirements in Figure 1.

In a large percentage of cases, sawmills are more than self-sufficient in energy from their residues. Many of them are self-sufficient in planer shavings alone. What does this mean in terms of dollars and cents? If we calculate the Btus available in the fossil fuels, like oil, natural gas, and butane, to the potential in wood residues, these are the kind of values which we come up with (Table 4). If we take natural gas at 10 cents a therm, the wood residue at 40% moisture content is worth about $11.50 a ton. Similarly for oil and butane. Oil is getting up around $15/barrel which makes the wood residue potential about $28 a ton. Butane or propane is around 45 cents/gal. in B.C., so that the equivalent value of residue is about $43 a ton. So, depending on what a mill is using as far as fossil fuel goes, the residue values vary considerably, and the higher the cost of your current fuel, of course, the more incentive there is to use wood residue. This again is dwelling on economics (Table 5), and it shows that we need 32,000 Btu per cubic feet of product, again from 40% to 13% moisture content. If we take the equivalent in natural gas, we need 3.14×10^4 per million board feet of lumber and at 15 cents per therm, this would be worth $4,710 per million. If we look at oil, we need 500 barrels per million board feet at $15/barrel. This costs $7500 per million board feet of lumber. And similarly with butane, we need 25,130 gal. at 45 cents a gallon and it would cost $11,300 per million board feet.

So, what kind of production should we have before we contemplate switching from a fossil fuel to trying to be self-sufficient in wood residues in manufacturing? Table 6 gives an indication of the kind of production we are looking at. This assumes that you are looking at a system which will give a 20% return on investment, which really isn't that much when you consider the uncertainties attached to those kinds of investments. Many of the systems of converting residues to energy are quite expensive and depending on the system used, may cost anywhere from one-half a million dollars to $2 million. If you look at the production required to give us a 20% return on investment in these kinds of investments and we're replacing gas at 15 cents a therm, then we should have a production of 25,000,000 board feet per annum. So we're not speaking of small sawmills; we are speaking about middle to large-size sawmills. However, because the costs of butane relative to gas is so high, the production we need to pay off this investment to get a 20% return is only 10 million board feet. It would depend on the fossil fuel we are replacing. And similarly, if the investment happens to be as much as $2 million, if you are going to replace gas at 15 cents a therm, we need a production of 100,000,000 board feet per year which is a fairly substantial size of sawmill. Similarly, replacing butane would be 40 million board feet.

If we look at the overall picture of Btu balance in forest products manufacturing, this is how it shapes up as far as I can gather (Table 7). I'm talking about the pulp industry as well. We need 33×10^6 Btu per ton produced and in-house availability, and this I gather in kraft manufacturing, is about 18×10^6 Btu per ton. So we can see that the pulp industry is in a deficit position. Lumber, as I indicated, is in a separate position. We need about 3×10^9 Btu per million board feet and we get about 6×10^9 Btu per million, so we have a surplus in lumber manufacture. In plywood manufacture, we need about 4.4×10^9 per million square feet. We have only 1.7×10^9 from the residues, so plywood is in deficit, because we don't have as much in residues in plywood manufacturing as we do in sawmill manufacture of lumber. In shingles and shakes we have a large surplus. We need 278 million Btu per 1000 squares and we get 947 million, so we have a large surplus. If we talk about an integrated lumber and plywood plant we are pretty well in balance. For every million board feet of lumber we produce, we can manufacture 1000 square feet of plywood from the excess energy available from the sawmill residues.

You have probably heard quite a bit about manufacturing methanol from wood waste or wood residues and this is something we have been

involved with peripherally. To manufacture methanol from wood waste, you go through twelve steps which is kind of involved. If you look at production of methanol from various sources, we find that using the "producer" method to make methanol from natural gas, the plant costs would be $23,000,000 as opposed to $64,000,000 starting from wood waste, and $74,000,000 starting from coal. Also, the efficiency is much higher in trying to produce methanol from natural gas and coal than it is from wood waste.

Our stance is that producing methanol from wood waste at the present is really uneconomical and the approach and strategy would be to first produce methanol from natural gas. I will read excerpts from a memo Stu Evans prepared for an inquiry he had about production of methanol from wood waste and it illustrates our stance and what we think our strategy should be on the production of methanol. "Methanol is synthesized from natural gas at two plants in Canada, Medicine Hat and Cornwall, and 12 plants in the states. Methane is treated with steam and CO_2 under pressure with a catalyst to produce carbon monoxide and hydrogen. The resulting gas is reacted catalytically to form methanol. The process involves four relatively simple steps with the final one being to distill the crude methanol to a fine product. The gasification of any carbonaceous material such as coal, lignite, agricultural residues, garbage and wood waste can yield the gas from which methanol can be made. However, in contrast to natural gas, the crude gas from these raw materials requires several process steps to clean the gas, remove hydrocarbons and nitrogen and to shift convert some of the CO and water to H_2 and CO_2 in order to get the required 2 – 1 ratio of H_2 to CO. A further extra step is required to remove the CO_2 produced in the shift conversion. In fact, 12 separate steps would be required to refine methanol from carbonaceous solids. Among the above solids, coal conversion to synthetic natural gas is most efficient because it has the highest carbon and oxygen content. Plant efficiencies are: 61% from natural gas, 59% from coal, 38% from wood waste. The first requirement for methanol from wood is a wood gasification plant. To the best of our knowledge, there are no commercial-scale wood gasification plants operating in the world today. The only contender is a full-scale gasifier built by Moore Canada Ltd. for Ainsworth Lumber which is a plant in B.C. and which is still having serious start-up problems, and is not operating yet. In our view, the best energy strategy relating to methanol is to accelerate perfection of wood gasifiers as currently in place at this point in B.C. and to encourage the forest industry to use them. The simplest, lowest cost way to replace natural gas in present burners is surely to switch to producer gas from wood."

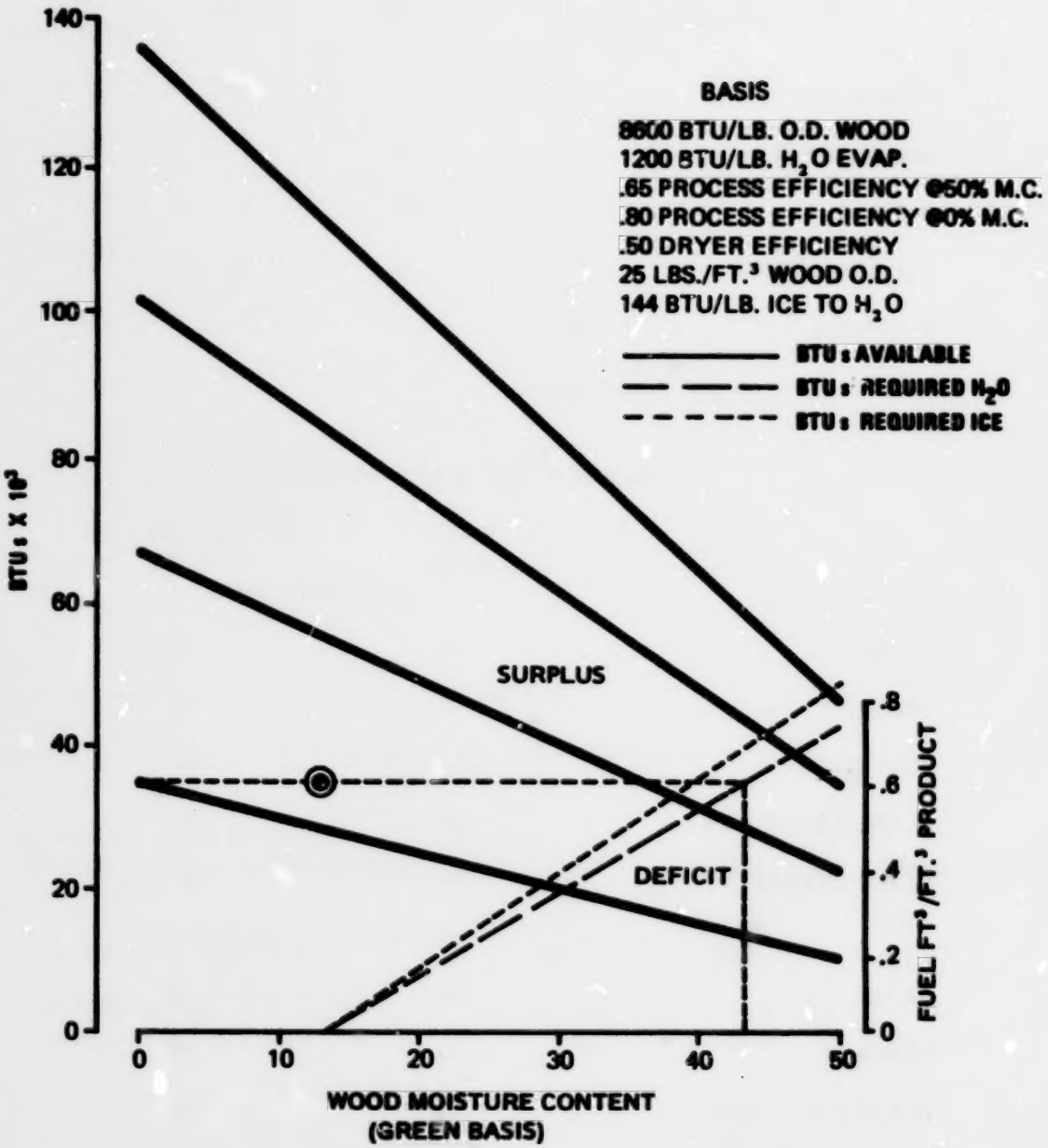
BASIS
8600 BTU/LB. O.D. WOOD
1200 BTU/LB. H_2O EVAP.
.65 PROCESS EFFICIENCY @50% M.C.
.80 PROCESS EFFICIENCY @0% M.C.
.50 DRYER EFFICIENCY
25 LBS./FT.^{3} WOOD O.D.
144 BTU/LB. ICE TO H_2O
BTU's AVAILABLE
BTU's REQUIRED H_2O
BTU's REQUIRED ICE
BTU's X 10^3
140
120
100
80
60
40
20
0
SURPLUS
DEFICIT
0
10
20
30
40
50
WOOD MOISTURE CONTENT
(GREEN BASIS)
.8
.6
.4
.2
0
FUEL FT^3/FT.^{3} PRODUCT

Figure 1

TABLE 1

BARK RECOVERY FACTORS

	CU. FT./CUNIT OF LOGS	REDUCTION FACTORS TRANSIT	VOIDS	BARK YIELD AT MILL CU. FT./CUNIT
W. HEMLOCK	20	.3	.2	11
AMABILIS FIR	15	.3	.2	8
D. FIR	28	.3	.3	14
LODGEPOLE PINE	11	.2	.1	8
W. SPRUCE	15	.2	.1	11

TABLE 2

PRODUCT YIELDS IN SAWMILLING

	BAND H'RIG	CHIPPER H'RIG
	CU.FT./CUNIT LOG	
BARK	11	10
SAWDUST	12	6
PULP CHIPS	31	43
PLANER SHAVINGS	10	10
DRIED LUMBER	44	39
	CU.FT./CU.FT. PRODUCT	
BARK	.25	.26
SAWDUST	.27	.15
PLANER SHAVINGS	.23	.26
TOTAL HOG	.75	.67

TABLE 3

PRODUCT YIELDS IN PLYWOOD AND SHINGLES

	PLYWOOD	SHINGLES
	CU.FT./CUNIT LOG	
PLYWOOD	49	
SHINGLES		47
LUMBER	9	
CHIPS	26	21
HOG	21	39
	HOG FUEL CU.FT./CU.FT. PRODUCT	
	.43	.83

TABLE 4

RESIDUE VALUES RELATED TO FOSSIL FUEL COSTS

NATURAL GAS $/THERM	.10	.15	.20
WOOD RESIDUE $/TON (40% MC)	11.50	17.50	23.00
OIL $/BBL.	15	20	25
WOOD RESIDUE $/TON	28.00	37.50	47.50
BUTANE $/GAL.	.40	.45	.50
WOOD RESIDUE $/TON	38.50	43.00	48.00

TABLE 5

ECONOMICS

1. Need 32,000 BTU/Ft^3 product from 40% to 13% MC (O.W. basis)
   = 2.67×10^6 BTU/M fbm
   = 2.67×10^9 BTU/MM fbm

2. NAT. GAS @ 100,000 BTU/Therm
   85% Efficiency
   Need 3.14×10^4 Therms/MM fbm
   @$ .15/Therm = $4,710/MM fbm

3. OIL @6.3×10^6 BTU/BBL @85% Efficiency
   Need 500 BBL/MM fbm
   @$15/BBL = $7,500/MM fbm

4. BUTANE @ 125,000 BTU/GAL @85% Efficiency
   Need 25.13×10^3 Gal/MM fbm
   @.45/Gal =$11,310/MM fbm

TABLE 6

PRODUCTION REQUIRED FOR 20% ROI ON FOSSIL FUEL REPLACEMENT SYSTEM

	INVESTMENT($)		
	500,000	1,000,000	2,000,000
	PRODUCTION (MM FBM)		
GAS @$ .15/THERM	25	50	100
OIL @$15/BBL	16	32	64
BUTANE @$.45/GAL	10	20	40

TABLE 7

BTU BALANCE IN
FOREST PRODUCTS INDUSTRY

INDUSTRY	BTU REQUIREMENTS	BTU IN-HOUSE AVAILABILITY
PULP	33×10^6 BTU/TON	18×10^6 BTU/TON
LUMBER	3×10^9 BTU/MM FBM	6×10^9 BTU/MM
PLYWOOD	4.4×10^9 BTU/MM FT^2 3/8"	1.7×10^9 BTU/MM
SH. & SH.	278×10^6 BTU/M SQS.	947×10^6 BTU/M

LBR. 2.9×10^9 BTU/MM FBM SURPLUS
PLYWOOD 2.7×10^9 BTU/MM FT^2 3/8" DEFICIT

Lumber Markets

F. Alan Taylor

In spite of forecasts of population increase and the doubling of demand for wood fibre by 2000, it is unlikely there will be any general shortage of wood for many years. As yet untapped sources, both temperate and tropical, should be capable of meeting the demands, but regional imbalances in wood supply and demand will become more pronounced, resulting in an overall increase in world trade in forest products.

North America produces 32% of the world's softwood lumber, consumes 31% and accounts for 45% of the total exports. Canada alone has 38% of world exports (mostly to the U.S.), although it produces only 10%. Russia is the largest single producer and consumer in the world and ranks behind Canada and Sweden in exports.

For wood-based panel products, North American predominance of consumption is very pronounced. Of a world consumption of 97 million cubic meters in 1973, 41% was consumed in North America, and 39% was produced here, but in panel products trade, North America is third behind Europe and Asia.

The importance of world trade to North American lumber and plywood industries should be put in perspective, being much more important to Canada than to the U.S. Canada produces only 10% of the world's softwood lumber, yet its exports account for 38% of world trade. These exports represent two-thirds of Canadian production, so changes in world trade patterns are of great significance to Canada. The U.S., on the other hand, exports only 10% of its lumber and is, in fact, a growing net importer.

For plywood, 85% of Canadian production is consumed in Canada. For the U.S. the figure is 93%. (Canada is the greatest per capita user of plywood).

Approximately 80% of Canada's lumber exports go to the U.S. but virtually no plywood is shipped there because of a 20% tariff.

Transportation has a tremendous impact on forest products marketing. For example, the Jones Act in the U.S. prohibits the shipping of U.S. goods from one U.S. port to another in anything but U.S. ships. Canada's exporters are free to use ships of any country.

In the Canada/U.S. rail market, freight rates from B.C., Alberta, Washington, Idaho and Oregon to common U.S. destinations have been similar for the last 70 years. Early in 1976, Canadian National and Canadian Pacific arbitrarily increased their rates on lumber shipments from B.C. and Alberta by 7%, placing Canadian producers at a competitive disadvantage with their American counterparts to the tune of about $3 per thousand.

The two current major deficit regions are Japan and Europe. Japan is an interesting example of how legislation can radically affect trade flows. The U.S. is a net importer of converted wood products, and yet it is a major exporter of raw wood in log and chip form. In B.C. we are prohibited in effect from exporting logs, yet until recently, the Japanese have not wanted to import much of our finished lumber. Japan prefers to import raw materials for application of Japanese labour, capital and technology to produce goods for domestic

consumption or export, and has built a large and complex forest products industry on this philosophy.

This position is currently moderating because of the growing reluctance of many countries to export unprocessed raw materials, and because of a growing deficiency in Japan's domestic forest resource. Indeed, the Japanese are shifting to a position of active encouragement, not only of imports of lumber and plywood, but also of investments abroad in wood-producing facilities. The combination of current economic, social and political forces is bound to provide foreign suppliers, including North America, with a greatly expanded market opportunity.

In Europe the timber market balance has been largely maintained by the supply from the U.S.S.R. and Scandinavia to the EEC countries, with occasional liberal dashes of imports from Canada and the U.S.

With the Scandinavians already pushing their allowable annual cut, and with European Russia up to and perhaps beyond its annual limit, it is unlikely there will be any major assaults on western European markets in the next decade. Therefore, the European market offers good prospects for North American producers.

In other products, there has been a rapid increase in particleboard and waferboard production in North America; these have made significant inroads into traditional end-use markets for plywood, such as wall and roof sheathing. More plywood production is thus likely to become available for export, throwing competitive pressure on Canadian exporters.

It is interesting to consider where our competition in the future will come from. The southern pine region of the U.S., where resource, capital, technology, labour and political stability have combined to foster increased and economic production, produced 30% of the U.S. annual wood supply in 1970. By 2000 A.D. it will produce some 55% of the supply and that will be an expanded market. They are now working on their "third forest."

This timber from the southeast U.S. is pretty impressive: straight, well-formed trees 25 years old can be typically 22 inches diameter, dbh. They have a high proportion of summerwood and they are easy to harvest.

A few years ago, the pulp mills in the East discovered that each pulp log contained at least a couple of 2 x 4 studs and they have made significant inroads into the Atlantic Coast cargo market, once considered the private domain of the B.C. coast shippers.

Hardwood lumber is a potential growth product, especially from Brazil, southeast Asia, eastern Europe and Japan, if production and marketing problems can be overcome. (Aspen is not the only hardwood with problems.) There appears to be some confusion about the future availability of hardwoods from Asia because of present over-cutting and lack of regeneration. This may be so, but the real competition for our softwoods will come from future generations of exotic long-fibre pines, planted on cut-over lands, to provide the base of products directly in competition with our own. Those who have travelled in New Zealand, Australia , Chile, Brazil, South Africa and even Spain and Portugal can attest to the rapid strides plantation forestry has made. The real significance of the tropical softwood potential is best confirmed by the fact that many foreign companies (including Canadian) are actively exploring or are already establishing in these plantation areas. There are Caribbean pine plantations in Brazil that reach saw timber size in less than 20 years, with the first thinnings for pulp coming out at seven years.

Their impact is close, and if North American producers are to retain their share of the world market against this competitive threat, they will need all the management and marketing ingenuity they can muster, and all of us must recognize that once our old-growth timber capital is exhausted, we could really be out in the cold.

Necessity being the mother of invention, it is likely that we will see large increases in reconstituted materials, as panel products, and trends to end and edge gluing of structural materials as the timber supply becomes smaller in diameter.

We can look for a reduction in the number of grades, less differentiation between some species and revisions to codes and standards that permit safer and more effective use of the timber resource.

CHINA

China stands out in terms of market potential. As is the case with the United States, it has substantial forests in the northwest part of the country and a high population density in the southeast. The national transport system of China is quite primitive and they have other higher priorities than to haul timber across China – a distance equivalent to crossing Canada.

If China really gets fully involved in foreign trade, they could import substantial quantities of forest products of all types; at the present time, they import only pulp.

Canadian businessmen have discussed the development of a timber trade with China and, at the present time China is trying to purchase logs for conversion from Malaysia and New Zealand. As far as North America is concerned, they are thinking in terms of squares for remanufacture. British Columbia businessmen anticipate that a modest trade of about 10 million fbm per year could develop within 3 to 5 years. The industry has attended trade fairs in China and has distributed copies of Council of Forest Industries of B.C. resource brochures with the text in Mandarin. In China, the government purchases all imports and re-sells to domestic operators.

ARABS

They have a good supply of petrodollars and their country is a good market area for lumber – it performs well in their climates. Doing business with the Arabs is something else again – they are really horse traders and hagglers. The amount of time it takes to consumate a deal and arrive at mutually agreeable terms of payment can drive a North American businessman up the wall.

The Russians are firmly entrenched in the Arab market and it will be tough to crack, but as long as the oil money is there the potential is very interesting.

METRICATION

Industry has settled on the sizes and is basically in agreement with the U.S. Industry, although there are still some minor but important differences that must be settled. It is unrealistic to expect to market two different standard sizes in the same country. At the moment, there is no urgency, as projected schedules for metric changes are unlikely to be met.

Sawmills

J. Dobie

I think that the message has been coming across from presentations made today–if an industry wants to be competitive, or a government wants to be competitive, then small-scale technology isn't really the way to go. If you want to be competitive in the marketplace and bring foreign exchange or money into the province, or the country, then it seems like the only way to go is to expand. Get into large-scale technology. It's entirely dependent, it seems to me, on what the political philosophy is in the country or province that you want to go into. If you want to provide jobs in small communities, then small-scale technology may be alright. Certainly, if you want to be competitive in the marketplace, it doesn't look as though small-scale technology is going to be the answer.

I want to speak about the sawmilling industry and look first at the forest resources of Manitoba, because one of the most important items that any forest products organization has to examine is their forest resource. There have been several classic examples of failure because the people who are making the investment didn't make a close examination of the resources they were about to utilize. A well-publicized example is a sawmill in British Columbia which cost $20 million for its infrastructure and went into receivership. The reason for its failure was that they really didn't know what they were going to put into that sawmill. Another reason was that the sawmill was designed by pulpmill people and they don't know how to design sawmills.

Most important for any sawmill enterprise is to have good knowledge of the type of resource which they have – the size of the resource, the amount of decay, the volume per acre, etc. Next I want to look at economies of scale. Then I want to look at sawmill integration and, finally, I want to talk about efficiency in sawmilling.

MANITOBA FOREST RESOURCE

Manitoba has a total area of 352,000 square miles and of this slightly more than half is forested (Table 1). There are 63,000 square miles of productive forest land. Ninety-three percent is government owned. Eighty-four percent of the cut is from Crown land – sixteen percent from private land. As is the case with most, if not all, of the provinces in Canada, the government owns the timber. The annual allowable cut is 2.13 million cunits, with about 1.6 million in softwoods and .52 in hardwoods.

Looking at the distribution of different species (Table 2), softwoods comprise 76 – 77% of the forest inventory on Crown land and these are mainly jack pine and black spruce. The hardwoods comprise 23%, mostly trembling aspen. So we have 77% softwoods and 23% hardwoods.

Recent data on the annual cut (Table 3) indicates that it varied from 444,000 cunits in 1970 to 742,000 and 636,000 in 1974 and 1976, respectively. Of this, pulpwood comprised 70%, sawlogs 26%. Softwoods comprised 90% of the actual cut and the softwoods taken out amounted to 36% of the annual allowable cut. Hardwoods comprised only 12% of the annual allowable cut. So this indicates that we still have over 60% of the softwoods which can be cut and as much as 88% of the hardwoods which are not being utilized.

Most of this timber occurs pretty well in central Manitoba. A large part of the volume which is available is in the central and northern zones and around Lake Winnipeg. I understand that most of the timber which is up in the northwestern area is already spoken for by Manfor. A lot of the timber in the northeastern area doesn't seem to have been utilized at all.

A look at the location of the industry in Manitoba shows that there is a concentration in the lower half of the province. The biggest enterprise in Manitoba is at The Pas. There is nothing in the east side at all and this area contains a considerable portion of the inventory. The reason this area is not utilized is that, at the present, there is no accessibility to this area. If the industry were to expand, it would pretty well have to be in this area, which means building accessibility (considerable sums of money). I don't know if there has been a good look at the resource in this particular area.

What proportion of pulpwood is there to sawlogs? What is the decadence and what is the resource best suited for? Before any expansion of the industry, this would have to be looked at closer before anyone invested money in that area.

Once having defined the nature of the resource, we go to the next step and determine what the resource is best suited for. If we determine that it is suitable for the production of sawlogs and lumber manufacture, then we go to the next step and that is to determine what type of sawmill or sawmills should be invested in to utilize that resource. That brings me to the second part which is economies of scale in sawmilling.

ECONOMIES OF SCALE

On economies of scale and economic theory, we usually deal with two time frames: one being the short-run and the other being the long-run. The short-run is defined as that period of time when all resources are fixed, manpower, plant size is fixed, material is fixed, no variables. The long-run is defined as nothing being fixed, everything is variable. That is, you're free to choose different sizes of plant, different volumes of manpower, everything's variable in the long-run. Figure 1 is an indication of the short-run cost curve in economic theory. It indicates that as your output increases, your average costs per 1000 diminish, which is quite a simple concept if you can think of a fixed plant, fixed resources. You produce 1000 board feet of lumber, it costs you so much; 2000, it costs you something less per M. The more you produce from your fixed plant, the less it's going to cost you per M. So this is a short-run average cost curve.

From that we go in economic theory to the long-run average cost curve (Figure 2). As I said, in the long-run everything is variable. The long-run average cost curve is usually called the planning curve in economics and it's called that because you can pick and choose whatever plant size you want. It's also called the envelope curve because it's the envelope of all the short-run average costs. These short-run average cost curves represent different sizes of plant. So once we determine the extent of the resource and the nature of the resource, and determine how much we have, we can determine what size of plant we are going to put in. We don't look at the longrun average cost curve and say let's build the biggest plant we can because average cost per 1000 is cheapest in that plant. That's only true if you use that plant to capacity. If you can't use it to capacity, then you have to look at other plant capacities.

For example, if we wanted to produce the volume of lumber indicated by the dotted line in Figure 2, it would cost less per M in plant 3 than in plant 4 because we are underutilizing plant number 4, so the right size of plant for this output will be plant number 3. That's why it's called the planning curve and that's why it's important to know the extent of the resources before we make any decisions about sawmill size. This is the theory of the longrun average cost curve and the short-run average cost curve. It's true of almost any manufacturing enterprise — as volume produced increases, production costs per unit output diminish.

Let's look at some of the evidence for this theory. We will look at some of the costs which involve production. First of all, we have our fixed costs or our plant costs. There have been a lot of studies made regarding plant costs relative to plant

size. People have come up with what they call the 6/10 rule. This is based on a lot of studies at chemical and petroleum plants in the United States. What it means is a plant of 100 units capacity costs x dollars and a plant of 200 units capacity costs x dollars times 2 to the 0.6 power, which is about 1.52 times. So if we double plant size, we don't double the capital costs of the plant. In this case, it's about 1½ times.

Using this principle, I had a look at the published costs of plants in British Columbia sawmilling and took the published costs against the estimated capacity and came up with this figure that to double plant size, costs increased by 2 to the .73 power, which means about 1.66 times. If you triple plant size, costs increase by about 2.23 times. This rule seems to have application in sawmilling as well as in chemical and petroleum plants, and probably has application in most manufacturing enterprises too. The important thing here is that as the plant size increases, the fixed cost per unit output decreases.

Looking at other evidence related to plant size, based on British Columbia figures, Table 4 shows that production wages, fuel and electricity costs and salaries do also diminish as plant size increases. I've related these to the value of shipments of mills, which is a surrogate for mill size. I took the smallest size as being the base of 100. As plant size increases, you notice that the index diminishes.

Production wages are 100 in the smallest plant size. When you get to the biggest plant size, these were reduced to 48 per unit output. So the bigger plants have a lower manpower cost per unit output. For fuel and electricity, the same thing happened by quite a considerable margin. If you take them in total, there is a significant difference. So our plant costs per unit output diminish as plant size increases and our variable costs also diminish as plant size increases.

Let's look at some information from Manitoba where there was a study done a few years ago (Table 5). They broke the sawmills into two size classes, one of them greater than 5 million board feet per annum output and the other less than that. This study showed that wood costs as a percent of net sales was smaller in the larger size plants, salaries and wages were fairly comparable as were fuel and electricity, materials and supplies, and miscellaneous. Then we come to residual, which is considerably higher in the larger plants. This residual happened to be depreciation and profits. Here, again, is evidence that the larger-size plants were the more profitable. In Manitoba there is a preponderance of small plant sizes. The big majority of the plants are under 15,000 fbm per eight-hour shift.

I want to give you some information from British Columbia related to the same type of thing. In 1955, we had 2500 sawmills in British Columbia Interior. Ninety-two percent of those were in the small-size category, from 11-50,000 fbm per eight-hour shift. Formerly, we had many more sawmills. Then we jump to 1971, look at the distribution, and see that the number of plants has dropped to 650. The lumber production per annum was 4.9 billion fbm in 1955 and in 1971 it was 9 billion. What happened to the distribution? It moved toward the larger-size plants and 92% has dropped to 64% in the smaller size plants. The proportion in the larger-size plants increased from '55 to '71. If we look at new capacity from '69 to '72 in British Columbia, again we see a further change, a further drift of plants to large sizes. There were 35 new sawmills in British Columbia from '69 to '72 and the trend has been to the larger-size plants. Thirty-seven percent of these are actually up in the range of 150-200,000 fbm per shift. The reason is fairly obvious; the bigger the plant, the cheaper the manufacturing costs. If you want to be competitive, you have to talk about fairly large-scale technology. British Columbia lives or dies by its forest products industry; it has to be competitive and that's the reason for the trend in sawmilling as you see it in British Columbia.

SAWMILL INTEGRATION

I next want to talk about sawmill integration. What size of plant should we have before we talk about putting in a chip manufacturing facility in the plant? The answer is that it depends on the prices which we receive for the chips. It depends on what kind of return we are looking for on that

investment because, if we make an investment, surely we are looking for some kind of return on it. And it depends on the lumber production per shift. Let me put it this way – if you want to invest in a chip manufacturing facility (and this is based on a capital investment of $300,000, which it would cost for a reasonable chip manufacturing facility in a sawmill) – if your production is 30,000 board feet per shift and you are working 480 shifts per year of two shifts per day, and you want a 20% return on your investment, then you have to get about $20 per ton of chips (Figure 3). If your production is only 20,000 per shift and you are working one shift per day of 240 shifts per year and, again, you want to make 20% return on that investment, then you have to get $40 per ton. Before you make an investment in chip manufacturing facilities, you had better figure out how many shifts you are going to work, what your production per shift is going to be and how much you are going to get for those chips. That's really all you can say about what size of plant you should have.

Now, just a reminder about what we get from a sawmill which has a chip manufacturing facility with it – and this is based on a chipper headrig-type mill (Table 6). We get about 38% lumber, about 43% pulp-chips, 6% sawdust, 10% planer shavings and about 10% bark. You heard about TMP. Pulp chips and planer shavings, if we are talking about integration, go to the TMP plant. Sawdust and bark could go to energy, which was talked about.

Let's talk about TMP-sawmill integration. An economical TMP plant is one which produces about 50,000 tons per year. Fifty thousand tons per year means about 42,000 cunits of wood based on a 95% yield (Table 7). If we need 42,000 cunits of wood for an economical TMP plant, what it means if we go to sawmill size is this: the planer shavings and the pulp chips are equivalent to 53% of the sawlog yield together, which is equal to that 42,000 cunits. If that is the case, that means that we need 80,000 cunits of sawlogs for the sawmill to give you an economic size TMP plant. It doesn't have to be one sawmill, it could be two or three together, but this is the kind of input to the sawmill or sawmills that we would need to get that economic size TMP plant – 80,000 cunits. If we have a lumber recovery factor of 6 board feet per cu. ft. of wood, then lumber production would be 48 million board feet per year. So about the minimum size of lumber production to support an economic size TMP plant would be around 50 million board feet per year. Again, we're not talking small scale.

What about integrated sawmill-plywood plant? If we look at a fairly average size plywood plant, they can peel about 8,000 cu. ft. per shift (Table 8). Depending on what proportion of veneer logs we have with the material going into the sawmill, it means that we are going to have different volumes of wood to the sawmill. If our veneer mix is 10% of the total input to the sawmill, and we need 8000 cu. ft. per shift in the plywood plant, it means that we are going to have to have 720 cunits of sawlogs for the sawmill in that shift. That means a lumber production of 430,000 board feet per shift which isn't a small plant. If we get as much as 30% veneer logs in our sawmill input, it means that we need 187,000 cunits of sawlogs per shift in the sawmill and that is equivalent to the lumber production of about 112,000 board feet per shift. So for integrated sawmill-TMP, integrated sawmill-plywood plant, we are talking about big mills.

SAWMILL EFFICIENCY

The final point I would like to talk about is efficiency in sawmilling. These are based on studies, again mostly done in British Columbia. As I said, British Columbia lives or dies by its forest products industry and we are having a lot of competition in the marketplace and the competition is not going to get any less, particularly from the southern pine states.

One thing that we impress upon the industry or try to impress upon the industry is that they really have to become more efficient if they wish to remain competitive. Not only remain competitive, but to maintain their place in the market. We have done a lot of studies which indicate that there are inefficiencies throughout the sawmills which could be rectified and, in so doing, would reduce manufacturing costs or increase the yields from the raw material resource. Some of the fairly obvious areas which could be made more efficient in

sawmilling are concerned with log lengths, sawtooth widths, lumber sizes and mill productivity.

Studies in British Columbia have shown that only 20% of the log lengths we measured in the sawmills were on size. This is after bucking on the sawmill deck. Eighty percent were off size. Most of them oversize or undersize. Taking a conservative estimate of the increase in lumber production which could be achieved if log length accuracy was improved, we came up with a figure of 2% of the annual production, which doesn't seem a lot until you think that British Columbia puts out somewhere around 10 billion fbm per year. Two percent of that would be 200,000,000 fbm!

The next area is in sawtooth widths and despite the modern technology available and the improvements in sawing processes which have been made over the years, much of the industry is still using excessive tooth widths in their saws. We found that 45% of the headrig and edger saws which do most of the manufacturing in their sawmills were what we call oversize. They were over a quarter inch thick. Again, making an estimate of the increase of production possible from improving the sawtooth widths, we come up with a figure of 3%. Then we looked at the lumber sizes. We found that for any given lumber size, the variation in sawing was one-half inch. This is the actual range we encountered and we figure that this is the range which currently exists. With a reduction on the average lumber size to acceptable limits, an increase of 5 percent per annum in lumber production from the same raw material input is possible.

One of the biggest inefficiency factors we found in our studies was down time and this is underutilization of capacity in the sawmill. We found that there was 13.6% in our older coastal sawmills which isn't bad actually. There is a certain amount of down time in any sawmill that is unavoidable. We found that in our interior sawmills which are mostly new sawmills that it was 34.6%, so that essentially they were only working 2/3 of the available working time. This was for various reasons including the in-feed, the headrig, edgers and resaws, waste conveyors and chips. This is headrig down time and we feel that if the headrig isn't working, the mill is under-producing. The most important thing for a sawmill is to keep the headrig working and to utilize that capacity to reduce your annual manufacturing costs.

The reasons for down time were many but a lot of it was due to inadequate sawmill design, inappropriate combinations of equipment. One of the things that we have done on our program in the Forest Products Lab is to devise a sawmill-simulation design technique. What this does is take a proposed sawmill design with a proposed lumber output, the proposed product that the operator wants to produce and the input that the sawmill operator provides it with and run this through a computer simulation model and we tell him where the bottlenecks are going to be in that sawmill. This is our effort to eliminate this large percentage of down time which occurs in the sawmilling industry in the interior of British Columbia. We can point out the bottlenecks in his proposed mill design and recommend changes whereby he can improve his flow through the mill and thereby improve his productivity and reduce his costs.

One of the other areas where operations could be improved in sawmilling is in yields from the raw material input. Even if you have correct lumber sizes, even if you have good bucking and even if you have narrow kerf saws, and even if you have a very low proportion of down time, you can still improve your process by making the right decision about how you cut up your logs.

It's particularly important with sawlogs that you make the right decision at the headrig about what you are going to cut out of that log. If you make the wrong decision, then you are going to reduce your yield, and we found out that's exactly what was happening in many of the new sawmills in British Columbia, that the operator wasn't making the right decision. It really wasn't his fault because sometimes the operator was faced with as many as 10,000 decisions per shift to make on logs going through the sawmill. It was just humanly impossible to make the right decisions because of the variables which affect the yield in a sawmill; the size of the logs, the diameter of the logs, the shape of the logs, the taper of the logs and there is no operator existing who can guess all those things accurately. For example, take a chipper headrig with

machine setting you can select to get the different yields. A typical pattern would be two 2 x 4s from a small log and, as your log size increases with that same pattern, then you can understand that your lumber recovery factor must diminish. There is a certain diameter where you change your pattern to increase your yield and if you miss that diameter then your yield continues to decrease.

The operator really doesn't stand a chance of making the right decision with all the variables which he encounters in all of the logs sawn in a shift. The answer which is becoming increasingly apparent, and increasingly used by the sawlog industry in Scandinavia, is the application of sawlog scanning and computer technology. This is the area where I see probably the biggest introduction of new technology in the sawmilling industry. Again, we are talking about fairly large-scale sawmilling technology. This is the area of helping the operator to make the right decisions to get the maximum yield from that log.

We can put scanner and computer applications right through the sawmill from bucking deck to the trim saw. Studies have been done which indicate that the potential payoff from these scanners is anywhere in the region of 10 – 20% increase in yield. The capital investment can be pretty high. Depending on how many applications you put in the sawmill, it can range anywhere from $50,000 – $600,000. However, the payoff of most of these applications occurs within a year. This is where I see the biggest introduction of recent technology in the sawmilling industry.

The message is that if we want to be competitive, we are talking about large-scale technology. If we don't want to be competitive and the philosophy is to provide work in isolated communities, then small-scale technology may be okay and may be the answer. But if we are working in foreign markets and we have to be competitive and we have to achieve maximum efficiency in the sawmilling industry, then these are the directions we see that the industry must take in becoming more efficient.

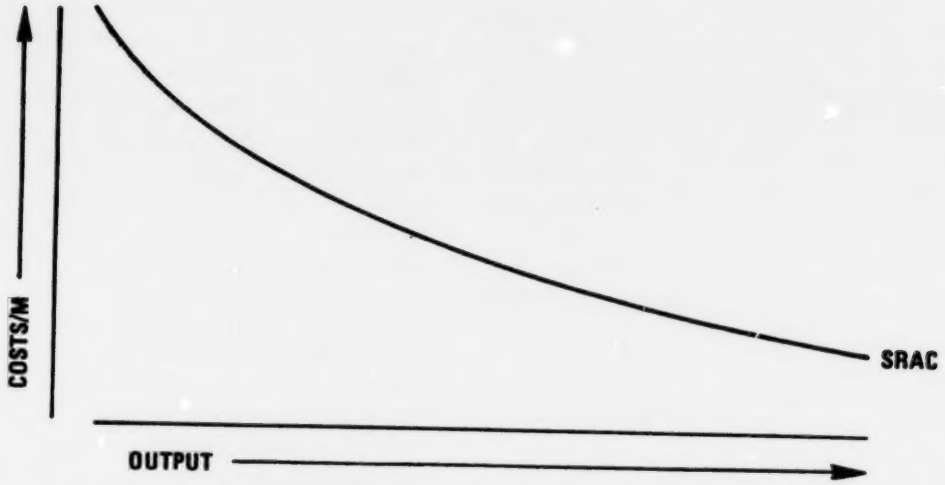

Figure 1

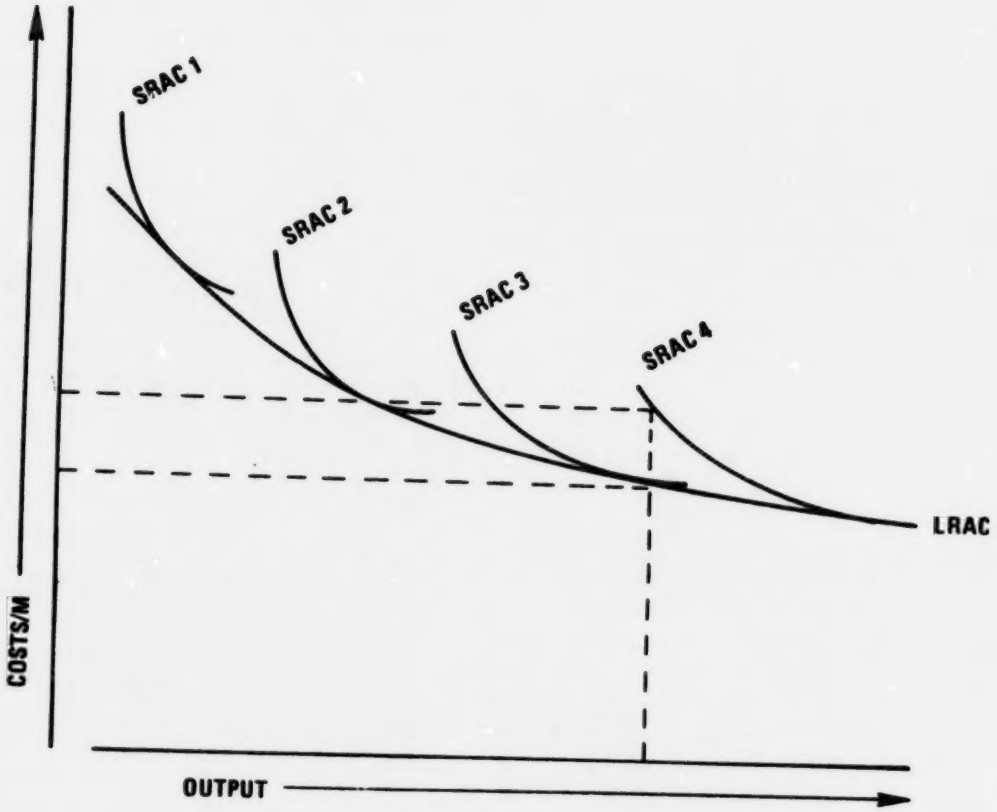

Figure 2

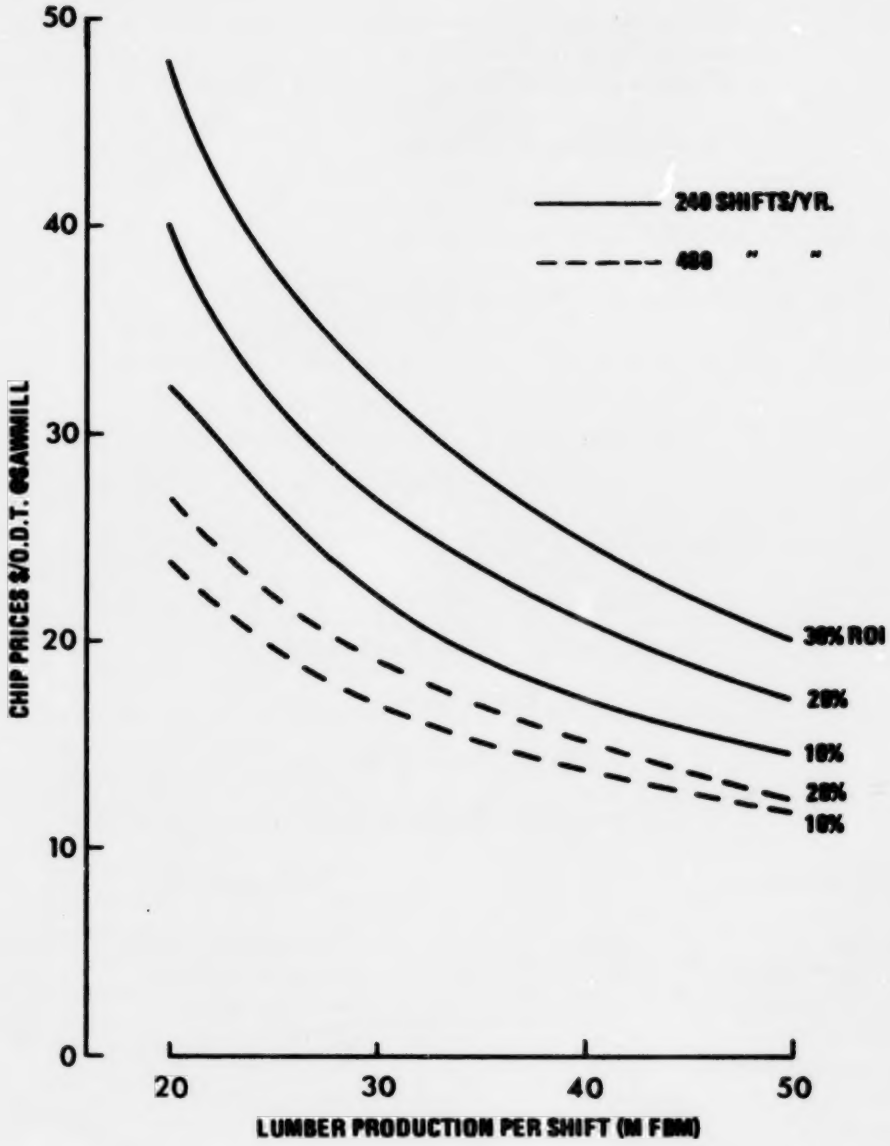
50
40
30
20
10
0
CHIP PRICES $/O.D.T. @SAWMILL
240 SHIFTS/YR.
480 " "
30% ROI
20%
10%
20%
10%
20
30
40
50
LUMBER PRODUCTION PER SHIFT (M FBM)

Figure 3

TABLE 1

MANITOBA

FOREST STATISTICS

1. 252,000 SQ. MLS. TOTAL AREA
   133,453 SQ. MLS. FORESTED
   63,259 SQ. MLS. PRODUCTIVE FOREST LAND

2. 93% GOVERNMENT OWNED

3. 84% CUT ON CROWN LAND
   16% CUT ON PRIVATE LAND

4. ANNUAL ALLOWABLE CUT ≈ 2.13 MM CUNITS
   1.61 MM SOFTWOODS
   .52 MM HARDWOODS

TABLE 2

MANITOBA

FOREST INVENTORY

CROWN LAND 160 586 660 CUNITS

SOFTWOODS		HARDWOODS	
JACK PINE	20.9%	TREMBLING ASPEN	17.5%
BLACK SPRUCE	46.3	BALSAM POPLAR	2.6
WHITE SPRUCE	6.7	WHITE BIRCH	2.9
BALSAM FIR	1.9	OTHER	0.3
TAMARACK,LARCH	0.8		
E. CEDAR	0.1		
TOTALS	76.7		23.3

TABLE 3

MANITOBA

ANNUAL CUT

	CUNITS
1970	444820
1971	549370
1972	648000
1973	645700
1974	742000
1975	664270
1976	636000
PULPWOOD	70%
SAWLOGS	26%
OTHERS	4%
SOFTWOODS	90% (36% AAC)
HARDWOODS	10% (12% AAC)

TABLE 4

BRITISH COLUMBIA SAWMILLS

VALUE OF SHIPMENTS PER MILL ($'000)	INDEX OF COSTS PER DOLLAR OF SHIPMENTS			
	PRODUCTION WAGES	FUEL & ELECTRICITY	SALARIES	TOTAL
100 - 199	100	100	100	100
200 - 499	84	71	100	85
500 - 999	62	49	66	61
1,000 - 4,999	48	39	55	48
5,000 +	48	18	41	44

SOURCE: STATS. CANADA

TABLE 5

MANITOBA SAWMILLS

ITEM	LARGE MILLS (4) (>5MM FBM p.a.)	SMALL MILLS (119) (<5MM FBM p.a.)
	COSTS AS % NET SALES	
WOOD	43	51
SALARIES & WAGES	24	27
FUEL & ELEC.	1	2
MATS. & SUPPLIES	9	9
MISC.[1]	8	7
RESIDUAL[2]	14	4

[1] INCLUDES COMPANY PAID EMPLOYEE BENEFITS, PROPERTY TAXES, INSURANCE, LEASING & RENTALS
[2] INCLUDES DEPRECIATION AND PROFITS

TABLE 6

SAWMILL PRODUCTS

	%
LUMBER	38
PULP CHIPS	43
SAWDUST	6
PLANER SHAVINGS	10
BARK	10

PULP CHIPS & PLANER SHAVINGS → TMP
SAWDUST & BARK → ENERGY

TABLE 7

INTEGRATED SAWMILL – TMP PLANT

1. 50,000 tpy TMP
   ≈42,000 CUNITS WOOD (.95 YIELD)

2. PULP CHIPS & PLANER SHAVINGS
   42,000 CUNITS = 53% SAWLOG YIELD
   =80,000 CUNITS SAWLOGS TO SAWMILL

3. LRF = 6.0
   LUMBER PRODUCTION = 48 MM FBM p.a.

TABLE 8

INTEGRATED SAWMILL – PLYWOOD

1. PRODN. CA. 4 BLOCKS PER MIN.
   400 MINS. PER SHIFT
   AV. BLOCK 5 FT^3
   =8000 FT^3 PER SHIFT

2.

VENEER LOGS % SAWLOGS	SAWLOGS TO SAWMILL/SHIFT	LUMBER PRODN./SHIFT
10	720 CUNITS	430 M FBM
20	320 CUNITS	190 M FBM
30	187 CUNITS	112 M FBM

Use of Wood Residues

G.E. Styan

I want to discuss the pulping residues and underutilized species, particularly aspen. My presentation will be broken into three sections: the pulping of whole-tree chips, thermo-mechanical pulping (better known as TMP in the trade; its the fastest growing technology in the pulp and paper industry) and refiner mechanical pulping of aspen.

I. WHOLE-TREE CHIPS

Insofar as the pulping of whole-tree chips is concerned, I will be brief because neither Manitoba nor Saskatchewan has a fibre shortage. There are a number of terms that are used in whole-tree utilization and many of them are interchangeable. Generally, the concept of whole- or full-tree utilization refers to the use of all tree components of mature trees of preferred species. The concept of full-forest utilization, on the other hand, includes the use of all usable fibrous material on or beneath the forest floor. The major problem with whole-tree utilization is in upgrading the chips so as to increase the usefulness of such material in pulping, etc.

Usually with whole-tree utilization in North America we assume that everything from the stump up will be harvested. This will provide, with the top and branches, about 30% additional biomass relative to the bole, but only about 10% of this will be wood. The other 20% consists of what is called technical foliage, a mixture of leaves or needles, cones and twigs, and bark. This material is not suitable for use in any of the chemical or mechanical pulping processes. Sawmill chips generally contain 1% or less of bark together with some grit and dirt, but what about whole-tree chips? In addition to the merchantable bole, the top and branches produce less than 50% chips with some attached bark, and more than 50% as loose bark, foliage, twigs and cones. From the standpoint of pulping, therefore, we are dealing with a relatively low quality fibre source.

To repeat, the major problem is to upgrade these chips to increase their use in pulping. Right now the technology is such that we can't consider using them for mechanical pulping. If we could upgrade them to a point where we could use them for mechanical pulping, then we'd have sufficient technology to enable their use in kraft pulping.

I would now like to cover the problems that you are going to meet if you use whole-tree chips or full-forest chips in kraft pulping. The major problem in the large percentage of the material that is harvested is the grit and dirt. This starts right at the handling. It wears out equipment and creates real problems with maintenance and replacement. In storage of whole-tree chips, the foliage and the bark are more subject to microbiological attack. They heat up the pile more quickly and accelerate the processes of chip deterioration. Considerable losses of wood fibre have been reported because of spontaneous combustion of stored whole-tree chips. In processing, whole-tree chips are a problem in almost every unit in a chemical pulp mill. Digester packing is reduced and the resultant digester bottleneck reduces mill capacity. Quality problems are also manifested; these take the form of lower yield and lower quality (both in strength properties and increased dirt count).

The use of whole-tree chips is accompanied

by increased comsumption of cooking and bleaching chemicals. Foliage and bark consume more than their fair share of chemicals and produce less than half the pulp obtained from the same weight of wood. The presence of larger quantities of calcium (as the oxalate) in bark relative to wood causes scaling problems in the digester and throughout the mill. In pulp washing, additional black liquor foaming is observed and defoaming agents may be required.

Almost every kraft mill in North America is recovery boiler limited. In other words, their bottleneck is the recovery boiler. There is a higher solids loading per ton of pulp because of the lower yield. In bleaching, there is a higher bleach chemical usage. Obviously, if you use whole-tree chips, you are going to reduce the capacity of your pulp mill. If you can upgrade the chips so that you can use them in mechanical pulping, which means you really have to get down to the area of 1% bark with virtually no foliage, then you won't have a problem in the kraft mill. But with the present technology available for upgrading whole-tree chips the conclusion is that you will reduce the capacity of your pulp mill. The only time you can reduce the capacity of your pulp mill is in times when you can't sell the pulp. But then when you can't sell the pulp, you have to get a high quality. If you go to whole-tree chips, you reduce the quality of your pulp. So you are beat whether the market is good or poor. In conclusion, the present technology to upgrade these whole-tree chips is not sufficient to make their use in the pulp mill economical unless you are in a real fibre-short situation.

II THERMOMECHANICAL PULPING

I would like to move now to thermomechanical pulping. You may not think this is related, but thermomechanical pulping is related to the utilization of residues and to getting more from your forest. Prior to 1960, there was no commercial mechanical pulping technology that could use wood residue. All had to use roundwood. In 1960 refiner mechanical pulping was first commercialized in the Pacific Northwest, a high lumber-producing region with a lot of unused residues. Technology was therefore developed to use these residues in mechanical pulping. In 1968 the Swedes commercialized thermomechanical pulping; I will now refer to thermomechanical pulping as TMP. This is just second generation refiner mechanical pulping. It uses chips, sawdust and residue refined between two discs under pressure. TMP provides a unique opportunity for small forest products companies. It is an opportunity for decentralization of the pulp industry and it exists because of the economy of scale. You can economically operate a much smaller pulp mill with TMP than you can with chemical pulping. It provides an opportunity because, although you can go small with conventional groundwood; TM pulp has considerably better quality with strength possibly twice as strong as conventional groundwood. Again, I would like to emphasize that TMP is the fastest growing technology in the pulp and paper industry.

Now I would like to discuss briefly the product history of the established Canadian pulp and paper industry. There are basically just two products, newsprint and market pulp. In the past, the pulp and paper industry was dominated by the newsprint sector, so much so that, at one time, almost three-quarters of the Canadian pulp production was converted into newsprint. Thus, whenever one talks mechanical pulp to the established CPPI, they equate it with newsprint.

The other area, market pulp, grew very much in the '50's and '60's and was dominated by the bleached kraft mills. Market pulp is usually equated with bleached kraft pulp. Keep these two things in mind:

Mechanical pulp = newsprint

Market pulp = bleached kraft pulp

In 1935, three-quarters of Canada's pulp was converted to newsprint. That was the peak of the domination of the pulp and paper industry by the newsprint sector. Since then newsprint has gone down on a relative basis in importance. At the same time, market pulp started to increase and around 1950 the bleached kraft mill came into its own. In 1974 in Canada the export dollars raised from market pulp were more than from newsprint. This was the first time since 1912 that, on an export basis, market pulp brought in more money

than newsprint. The point I want to make here, and it is the focus of the mechanical pulping program of the Western Forest Products Laboratory (WFPL) is that newsprint is going down in importance. In the strategy of the rest of the world, in the U.S and Scandinavia particularly, this trend is expected to continue. Also, from the strategy of the Scandinavian countries, our major competitors, the trend for export pulp indicates that Canada should be producing more market pulp. At present, nearly all the TMP that Canada produces goes into newsprint. Newsprint is going down in importance. Market pulp is going up in importance. I ask why doesn't the CPPI look at TMP for market pulp? The established CPPI says "We don't want TMP for market pulp. Mechanical pulp equates with newsprint". I spent a few years fighting this at MacMillan Bloedel and finally gave up. Now why do I say TMP for market pulp? If we take a look at all the environmental factors that must be taken into account for exploitation of technology, we see that the market is very favourable for marketing TMP. I have broken the total environment down into four factors: ecology and its pollution, capital, resources (fibre, energy) and the last one, marketability. In the '50's and '60's the environment was very favourable for kraft pulp. It was an excellent quality pulp. We had lots of fibre, lots of cheap energy and, most of all, there was lots of capital available to the traditional manufacturing industry. The government did not control as much capital. We had a much looser environment for raising capital. But today this environment has changed significantly. There are two areas I would like to focus on: capital, which is a major advantage, and pollution. The pollution aspects are quite straightforward: chemical recovery is not required, there is a higher fibre yield, there's no air pollution and much less water pollution; in short, TMP has a very significant ecological advantage. With respect to resource availability, the main advantage is that there is a 95% yield compared to a 42% yield for chemical pulp. On the energy side, there's a disadvantage, because there's a higher net energy consumption by TMP. But that energy side is rather interesting. In Japan 70% of the mechanical pulp produced is via refiners. Refiner mechanical pulp, TMP included, takes considerably more energy than stone groundwood and energy is a high-cost factor in Japan. So just how important energy is in this whole setup I'm just not sure. Fibre is more important in Japan. They can't afford to grind sawlogs in Japan.

Let's go first to the major advantage which is capital requirement. Capital costs per daily ton are three times as much for kraft. Economy of scale – you have to go four times as high for a kraft mill as you do for a TMP mill. The cost of a kraft mill is about $250 million compared to $20 to 25 million for a TMP mill. This is a ratio of about 10. Therefore, if you want to compete in the market today and you decide you are going to build a kraft mill like everyone else has done, you have to have ten times the amount of capital to be competitive that you do with a TMP mill. This capital cost advantage for TMP is maximized for a market pulp mill. In the early days of setting up a newsprint mill, for example, the economy of scale dictated that you had to go to a minimum of 400 – 500 tons per day market mechanical pulp mill in Quebec. It shipped its pulp wet because at that time the technology for flash drying pulp was not good. They overdried it. You couldn't disperse it, the paper maker said. He didn't want anything to do with it. Canada grew through selling pulpwood initially and then grew through selling market mechanical pulp. The technology then was considerably different. The bleaching technology was different and the drying technology was non-existent and they shipped the pulp wet. They couldn't store it so they shipped it wet and it deteriorated.

In order to improve the marketability of TMP, there are three things that must be done. One is to develop more end uses. In Scandinavia, about 50% of the TMP produced goes into newsprint. Another 20% is market pulp; about 20% is used in board production and 10% in publication or higher grade paper. In Canada, about 90% of our TMP goes into newsprint. We have one mill in Quebec which makes TMP out of sawdust and shavings that goes into paperboard. But as far as exploitation of TMP in Canada goes, the Canadian industry says newsprint and that's it. We have to develop more end uses. If we don't, we can' t market pulp. This idea of marketability and developing more end uses is being exploited by the Swedish pulp and paper industry and in Scandinavia generally. We have to improve the strength even further. In Scandinavia

their biggest money expense in research and development is for thermomechanical pulping. Another thing that must be done, is to target for the highest pulp quality. There is a large refiner mechanical pulp mill which markets pulp in British Columbia. I say large – it's large for a market pulp mill – a mechanical market pulp mill. It produces about 320 tons per day. It's in northern British Columbia – Findley. They're having many difficulties in selling their pulp. When they first began producing bleached pulp, it was a very good market – '73, '74 I believe. They could sell anything they produced and they produced a poor quality pulp, not from the standpoint of brightness, but it had a lot of dirt in it. They didn't care because they could sell it anyway. As soon as the market turned soft, nobody would buy the low quality pulps and they upgraded their technology until they had a reasonable product. Now they are hitting their market with a reasonable product, but they lost most of their customers when they had a poor product. Therefore, to produce a mechanical pulp for the market requires the use of the best available technology. I will talk about this more when I talk about aspen for refiner mechanical pulp.

The incentive to the paper maker is price. Look at the period 1954-76. From '54 to about '73, the price differential between market mechanical pulp and market bleached kraft pulp was constant, at about $65 per ton. In '74 to '75 it started to take off and it's almost $200/T. now. This is where you get into the area of price elasticity with market kraft pulp. The market kraft industry has tried to maintain their price of about $365 per bleached ton. They found they couldn't maintain it. They didn't know whether there was price elasticity in there, but they've dropped it down to $335/T. now and a further drop down to $300/T. is expected. The paper that has taken over on the market – the only paper product that's really doing well in the way of printing paper, is a lightweight coated paper. This contains 50% mechanical pulp. The reason that the paper makers have gone over to it, and it's selling well, is because of this $200/T. difference. Fine papers are being replaced in a lot of applications by lower-grade papers which contain more mechanical pulp and chemical pulps can't compete with them pricewise. I think this is the reason the price of market bleached kraft is now dropping, and I don't know where that difference will end up. But you can see that this is a tremendous incentive for a paper maker to use mechanical pulp providing it is of reasonable quality.

To conclude this section on TMP, the capital and the relatively small fibre requirement provide an excellent opportunity for a high growth rate in thermomechanical pulping, and that's what we are seeing right now. As far as the Canadian pulp and paper industry is concerned, in view of the strategies of the competitors and the customers Canada should continue to grow in market pulp. Marketability is the major restriction in the growth of TMP and because of this, we have to target for the best quality we can get through available technology.

III MECHANICAL PULPING OF ASPEN

I would like to spend some time on aspen because this is my area in mechanical pulping at present. I have some results which are pretty exciting. They are new and different and better than any published results. They might be a little premature – I haven't published any of this or presented it. Everyone is well aware of the state of Canada's aspen resource. It's poorly utilized. Only 6% of the estimated annual allowable cut is harvested. Less than 4% of the pulp and paper industry pulpwood is aspen. There are large stands with decay and the lack of applications for mill residue from aspen generally results in unfavourable economics for harvesting most of the aspen resource. Certainly there are problems with aspen lumber: because of the decay, the yield is poor for lumber.

What about mechanical pulp from aspen in Canada? There are three mills that produce 100% poplar mechanical pulp. These produce stone groundwood, which is conventional technology. Two of these use it for tissue and one, I believe, for groundwood specialty grades. The reason it is used for groundwood specialty grades is that it responds well to bleaching. It is brighter than the softwoods so you can get a good brightness pulp and a good printability sheet; but the strength is down. There is no aspen refiner mechanical produced pulp in

Canada. Generally, when seeking information, particularly in Canada, on poplar groundwood or poplar mechanical pulp, the information appears to be confidential and it is very difficult to find out what's going on.

In our program in the WFPL, we are looking at better ways of making mechanical pulp from aspen. When we get this aspen pulp, we want to look at the marketability aspects. We know the major problem of market mechanical pulp is marketability and so we want to look at this aspen pulp as a component for various furnishes, for publication papers, for tissue papers and even fine papers. Also, considering that most of the aspen resource is in the northern reaches, you wouldn't think of constructing a paper mill. You would have to look at aspen market mechanical pulp. This means that you would have to look at the processability. How would the paper maker look at this market pulp?

There are two tissue mills in Canada; one uses black cottonwood stone groundwood for tissue; the other one uses trembling aspen stone groundwood for tissue. We thought we would produce a coarse pulp of high freeness. By way of comparison, mechanical pulp used for newsprint is about 100 m Cfs. We were looking at this coarse pulp for tissue, comparing it to other mechanical pulps used for tissue. We bleached it because there is a market survey in the southeastern states that indicated that the greatest potential for market TMP was a 75 brightness grade for tissue. Aspen responds very well to bleaching – we got about 82 brightness out of a 4% peroxide treatment, which is costly at about $32 per ton, but the Swedes came out with an 80 brightness market mechanical pulp in '72 which was a very high profit pulp. The technology of this is well known and it's been used for 5 – 6 years in Scandinavia. We made a coarse pulp with the approximate bulk and drainage rate that you want for tissue grades and we thought that we should have a look at this. When kraft pulp first came out there was a problem with the paper maker. Sulphite pulp is much easier to beat and the non-integrated paper maker was set up for sulphite pulp. When kraft pulp came along, there was a problem of marketability with it because it took more energy to beat it for the paper machine. With mechanical pulp, this is even more true. In Japan they buy a coarse grade mechanical pulp from New Zealand and then refine it at high consistencies to prepare it for newsprint. We thought that the North American paper maker would go to a high consistency refiner and be able to use a market mechanical pulp. We therefore refined our pulp and got an excellent pulp with low bulk and high brightness; the strength of that pulp is comparable to spruce stone groundwood.

For tissue grade, you want a pulp with high bulk. For a printing grade, you want a low bulk. One of the things wrong with refiner mechanical pulp is generally that the bulk is too high. You get a lot of problems with printing. The WFPL aspen RMP pulp that was brightened with peroxide had strengths comparable (some slightly better, some slightly lower) to spruce stone groundwood. But the drainage was much better and the pulp much less bulky and much better for printing grades. We therefore concluded that the peroxide brightened aspen RMP is a better pulp than spruce stone groundwood for the paper maker. Its properties are much better than any of the properties reported in the literature.

One thing very important to the paper maker is drainage rate. If the pulp drains too slowly, it's too wet when it goes into the press end and, when it's wet, it's weaker and breaks on the machine. So not only is strength important, but drainage is too. This is why the strength-drainage relationship is very important to the paper maker.

For use in tissue grades we compared the WFPL brightened aspen RMP to a commercial black cottonwood stone groundwood produced in New Westminster, B.C. The aspen RMP had comparable strengths to the black cottonwood pulp, the bulks were similar but it drained twice as fast. That's the real advantage. Thus, with respect to tissue grade, the aspen RMP is better than the pulps the tissue manufacturers are using now. And the reason they are using the cottonwood and poplar is because of brightness. They can get up to 70 – 75 brightness quite readily, something more difficult to do with softwood. For a printing grade paper we compared a spruce/balsam fir mixture to a commercial aspen RMP. In the states, there is one mill

using trembling aspen for refiner mechanical pulp. This is what we produced in the lab. The strengths are very comparable to the spruce groundwood and most of the market mechanical pulp in the world is spruce. Probably 80% of the market mechanical pulp sold in the world is spruce stone groundwood. What I'm saying is that we can produce an aspen RMP that is comparable in strength to the spruce stone groundwood. The drainage rate would be approximately three times as fast as spruce stone groundwood. The bulk is significantly better. In making a comparison with work published to date we found that the TMP process, relative to RMP, is not as good for hardwoods as it is for softwoods, even for aspen. This is why we concentrated our program at the WFPL on open-discharge refiner mechanical pulping of aspen (RMP). The main thing we are going to focus on is the marketability. To improve the marketability, you have to look at the end use. One of the end uses we are going to look at is in lightweight coated paper, which is the fastest growing paper in the industry right now. It's because it can use 50% mechanical pulp. One of the advantages of this aspen RMP is its low bulk. Low bulk means it is very good for coated paper. A bulky pulp gives a rough paper which is tough to coat. If this aspen RMP proves out suitable for end uses such as tissue, publication grades and fine papers, then we've done a lot to solve the marketability problem.

The advantage of a 200 a.d.T. per day aspen RMP mill is that you need just 200 T. of fibre, since the pulp yield is probably about 94%. Right now, the potential is for a two-line market pulp mill which can produce 100 T. per day of tissue grade and 100 T. per day of printing paper grade. There would be competition – there's aspen in Ontario and Quebec and there are a lot of non-integrated paper mills there – tissue mills, etc., that they could look at for integrating aspen RMP with their paper mills. Probably the best application would be to integrate it with a sawmill. You'd have a use for this residue, either from an aspen waferboard mill or stud mill or sawmill. Again, the economy of scale is the most important feature of it. The biggest problem is the marketability and that's what our program will focus on.

Acknowledgement

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Utilization of Wood and Forest Residues in Reconstituted Panel Products

M.N. Carroll

In terms of good wood utilization, the range of particleboard products presents a shining success story. On the one hand, we have billions of square feet of particleboard made from the non-pulpable residue from plywood plants and sawmills, such as planer shavings, sawdust, and plywood trim. On the other hand, we have the structural particleboard, waferboard, fulfilling a forest utilization purpose by using poplar roundwood. Briefly, the particleboard industry found its market niche in North America in the furniture industry as the supplier of "core" board, in which particleboard replaced the glued-up lumber core previously used in the core of things like veneered tabletops. It went on from there to find a major market as floor underlayment because of the demanding nature of the thin plastic floorings for a smooth, blemish-free laying surface.

The first plant for waferboard was built in Idaho in 1955 but was limited to a decorative panel market. This was followed, in 1962, by a plant in Hudson's Bay, Saskatchewan. About 1970, the diminishing availability of peeler logs for plywood created a market situation in which eastern-made waferboard became competitive with western-made softwood plywood for purely structural uses such as floor, roof and wall sheathing. This led to a major expansion of Canadian waferboard capacity over the next few years, from about 70-million square feet per year to about 500-million square feet per year.

How then do these products fit into the picture in Canada? It is easy enough to say that Canada has lots or primary mill residue and lots of poplar in the northern reaches. But manufacture consists of three things: the raw material, the technology of conversion, and selling the product not just at a profit, but at a profit that justifies the investment in competition with other demands for investment capital. Canada has the raw material and the technology is available. It is in the market that problems begin. The biggest problem is the effect of economies of scale. Particleboard is a capital intensive industy. To get competitively low unit costs, the scale of manufacture has to be large, at least 300 tons per day. In a small plant of about 75 tons per day, the unit cost of manufacture can be three times that of the 300-ton per day plant. The larger the plant, however, the further one has to go to find a market, and that means that shipping costs become significant in the profit picture. It also means that raw material costs start to become a problem, since it is difficult to find a concentration of 300 tons of available softwood residue in one place anywhere in Canada, even in B.C. If wood residue has to be gathered from scattered sawmills, the cost of shipping it to the central particleboard mill becomes a drag on costs.

The question, then, is how does Canada compete with the existing large-scale mills in the U.S.? The answer is that we do not. As a broad generalization, a large mill in the U.S. (of which there are many) can make a particleboard, ship it to any place in Canada, pay the duty, and sell it cheaper than we can make it here in a new plant the size of any of the existing particleboard plants. To get a large-scale Canadian plant going, we would have to sell the board in the eastern U.S. to find markets big enough to absorb the production. This also means going to western Canada, where the large softwood sawmills are, and then paying the

shipping cost to send the board thousands of miles back to the East.

Structural particleboard, waferboard, is a slightly different story. At present it is not competing with American waferboard, but with plywood. However, Canada already has over-production in waferboard, so it has to be sold in the U.S. markets to use up the existing capacity.

Waferboard does not have the problem of finding concentrations of sawmill residues since it is made from poplar roundwood. Nor does it suffer from the fact that most of the softwood sawmill residue is in western Canada, since poplar is available in Ontario and Quebec, very close to the major Canadian and U.S. markets. However, if we look at that the other way around, it means that a waferboard made in western Canada has the burden of shipping costs in any attempt to compete wtih waferboard mills in Ontario. Ten or fifteen dollars per thousand square feet shipping costs on a product selling at a mill price of $150 per thousand square feet might not seem like much. But in an economic size mill producing 100 million square feet a year it means that the annual profit is reduced by one to one and a half million dollars!

Looking at it in yet another way, with poplar available in Ontario at a stumpage charge of $1.50, the value of poplar stumpage in British Columbia is a negative stumpage of about $12.00. In the middie provinces, the value is somewhere between these extremes. This of course assumes that harvesting costs in western Canada would not be higher than they are in Ontario, something that is not assured.

So it is not surprising that the major concentration of waferboard manufacturing capacity is in Ontario. Should the demand for sheathing rise above the ability of the plywood industry to supply economically, it would no doubt lead to an increase in the market value of waferboard by enough to cover the extra costs of shipping from western Canada and still operate a waferboard mill at a profit. But this does not change the picture for the investor, if he finds he can make another million dollars per year by building his plant in eastern Canada rather than western Canada.

For the so-called wet-process fiberboards, insulation board and hardboard, the overall picture is much the same, even though these can also be made from the dense hardwoods and particleboard or waferboard cannot.

All of this flies in the face of the evidence that there are two relatively small particleboard mills operating in British Columbia, and a major waferboard operation in Hudson's Bay, Saskatchewan. There is also a waferboard mill in Slave Lake, Alberta. However, one should recognize that both of these waferboard operations went through an initial stage of bankruptcy, and the one in Slave Lake is still closed down.

The main point here is that we cannot judge the economics of today by the economics of 10 or even 5 years ago. Until the shake-out in 1974, there were several small particleboard plants operating in the U.S., plants that were built in the early days of particleboard, in the 1950's. The capital cost of these plants was written off in the 1960's. It is likely that many were operating on mill residue that would have cost money to dispose of by landfill or pollution-free incineration, and many of these were selling their product into captive markets. However, when the price of petroleum fuel escalated, the mill residue suddenly acquired a positive value as a source of process fuel. At the same time, the large, modern particleboard mills built in the early 1970's created about a 35% over capacity in particleboard production that pushed prices to new lows. In addition, new stringent pollution controls imposed restraints that these old mills were not designed for. The combination of circumstances was too much. They closed down.

So it is not enough to have the raw materials, the technology and the capital. In our society the market place tells us what we can do, and we must build our plants in the right place at the right time. The particleboard business has become big business — high technology, large scale, large investment. It is no longer a field for the small entrepreneur, manufacturing on a small scale for local market. The market price of particleboard is subject to wild swings, partly arising from the cyclical nature of housing starts, partly from the tendency of the industry to swing between over-

capacity and undercapacity, and partly from the "garbage disposal" nature of the business. When demand is down, the plants running on mill residue pretty well have to keep running (even if the board is selling at a loss) at a level that keeps up with the rate at which mill residue is being created by the sawmills and plywood mills.

Waferboard does not have the same "garbage disposal" restraint, and because the present difference in the Canadian and the American dollar offsets the duty on board going into the U.S., there is an essentially untapped market in the U.S., limited largely by shipping costs and the competitive position of American sheathing-grade plywood. However, it is also likely that a new wave of expansion is about to take place in the U.S., and that the major U.S. forest products companies will scramble to establish a market position in this product which (to them) is a relatively new building product — even at the cost of creating a temporary overcapacity in waferboard production.

In summary, Canada cannot look to particleboard to use up dribs and drabs of mill residue. The market is dominated by U.S. mills with capacities up to 1000 tons per day. Waferboard shows some potential for expansion in Ontario and Quebec, but this potential depends on whether a sudden interest in waferboard production in the U.S. would create an overcapacity that would take years to absorb.

Wood and Foliage for Animal Fodder

R.W. Nielson

I have divided this talk into two parts: 1) wood for animal feed, and 2) foliage for animal feed. First I will concentrate on the wood.

The first thing you have to look at when considering wood for animal feed is what are the requirements of an animal feed? There are four major requirements: 1) energy, 2) protein, 3) minerals, and 4) vitamins. If we look at the traditional sources of animal feed for ruminants, we find that the forages, grasses, etc., can provide all of the requirments. However, grains are now used to a very large extent in feeding cattle and other ruminants because of the higher productivity obtainable when feeding them grain. There is a higher carbohydrate content and hence more energy value in grains. As a result, the animals gain weight much faster on such feed. If the particular feed product used is deficient in other ingredients, they can usually be added in supplement form. If you don't have enough protein you can add it in various forms. About the cheapest is urea that is basically just adding nitrogen, which the cattle can then synthesize into protein; or you can go the other route and add high-quality protein such as rapeseed meal or soybean meal, but this is much more expensive. Protein is one of the most important constituents of animal feed products. Minerals and vitamins can also be added as supplements, but in this case, the supplements are very inexpensive.

We have looked at feed requirements, but what is in wood that might satisfy these needs? On examining the wood chemical composition, we find that there are a lot of celluloses and hemi-celluloses. Depending on species, there might be 60 – 85% of this carbohydrate material. This carbohydrate is a potential source of energy, one of the four feed requirements. However, the problem in wood is that this carbohydrate content is bound up in the cell structure with lignin and is inaccessible to cattle in the natural form of the wood. As a result there has been much research done in an attempt to increase the digestibility of the carbohydrate material. If you examine some of the other chemicals in wood, there are basically two other categories: (1) extractives, which possibly may have toxic effects on the animals, and (2) ash, which could contribute minerals to the animal's diet. Cobalt and manganese are two of the minerals which are most common in wood.

If you examine the digestibility of various wood species in natural form, you get a large range (Table 1). Coniferous species are the least digestible, e.g. lodgepole pine is 0%, and I imagine jack pine is very similar. At the other end of the scale, you have aspen and aspen is about the most digestible of the tree species in North America. As a result, much of the work on increasing the digestibility of wood has concentrated on aspen.

A number of treatments have been studies in Canada and the United States in an effort to increase digestibility. I have just listed a few: high-energy electron radiation, vibratory ballmilling, the addition of anhydrous liquid ammonia, treatment with sodium hydroxide, sulphur dioxide, the use of white rot fungi, and steam treatment. The steam treatment has been studied recently in Canada. The problem with most of these treatments is that they are expensive, and can't be considered practical for use on a commercial basis. The one that probably shows the most promise is the steam

treatment and I would like to concentrate on that and relate some of the developments on this process.

In the late 60s, Dr. Bender at the Eastern Forest Products Lab worked on the steam treatment of various wood species including aspen. Aspen turned out to respond best to the steam treatment and all his subsequent studies related to steam treated aspen. He managed to get the digestibility of aspen up to about 50%, which is approximately equivalent to a medium-grade hay. The process was patented through Canadian Patents and Developments Ltd., and a short time later (in 1972) a non-exclusive license was issued to a company by the name of Stake Technology Ltd., and their objective was to commercialize the process. They have been working on it ever since. There are a lot of difficulties in bringing something from an experimental stage to getting it into commercial production.

Animal feeding trials, required to prove out the product, have taken considerable time. Initially, trials were done in Ottawa and Saskatchewan. The steamed aspen was used in beef finishing rations and in sheep fattening rations. These feeding trials indicated that aspen could be used as it was produced in the steamed form for both of these rations. In the feeding trials with pregnant ewes in Saskatchewan, there was high mortality in their offspring, but there were complicating factors in the experiment and it was not clear whether the aspen had anything to do with it. This question has not been resolved and current feeding trials are being carried out to help answer this question. There were further feeding trials carried out in Kamloops last year and they are going to be continued this year on cattle, including pregnant animals, to study the toxicity effects. I should mention that the Department of Agriculture is involved in these latest trials and they are interested in it because they've accepted the product for sale on a provisional basis. Their feeding trials are related to the acceptance of this material as an acceptable feed product.

If you compare the steamed aspen product to hay, one deficiency in the aspen product is that it does not have any protein in it, whereas hay does, and the protein content for medium-grade hay might be 6 or 8%. On the other hand, you have a continuous supply of the aspen product. You don't have a seasonal factor. Another requirement is that the animals and the raw aspen material are located in close proximity so that transportation costs are low.

There have been at least two economic studies done on this process. One 1975 estimate resulted in the costs shown in Table 2. This particular estimate was for an 80 tons per day plant and resulted in a total treating cost of $43/ton. The wood cost was actually about half of the total cost. The economics of the whole process are very sensitive to wood cost, and you want to keep this item as low as possible. If mill residues were available, that should be a more economic source of material. Sawdust would probably be the cheapest, and could bring the costs down considerably. Land clearings in the agricultural belts here in Manitoba involve a lot of aspen and right now it is just burned. It's value cut and assembled in a pile in a farmer's field is just about $0. If you started using it, the farmer would want something for it, so its value would increase somewhat, but would certainly be less than $21/ton. The 80 ton per day plant size is rather large. This was the initial concept, but things have since been scaled down. Stake Technology Ltd. is now talking about plants in the range of 10 – 20 tons per day and the only cost analysis I have seen indicates that the processing cost is much the same as was estimated for the 80 ton plant. The concept of the portable plant arose because so much material is produced from an 80 ton per day plant as to cause a shipping problem. Transport costs for raw material and finished product must be minimized. The ideal would be to have the small plant which could serve the local area within a 20 or 30 mile radius, and the plant could possibly be owned by a farm co-operative or an individual farmer who had enough animals to feed.

In summing up, the only real thing you are going to get out of any treated wood product for animal feed is the energy value. You still have protein, minerals and vitamins to make up from other sources. With steamed aspen, you get a digestibility of about 50% which is equivalent to medium grade

hay. This is not as high as the aspen's potential as indicated by a carbohydrate content in the aspen of 79%. Presumably, there are people who are hard at work in their labs trying to raise the digestibility from 50 to 79%, and if they ever do that they will have a very good product.

Foliage for Animal Feed

Wood only has one thing in it useful for animal feed – energy value. Foliage has a different composition and is worth looking at to find out whether it has anything more to offer. The WFPL involvement with foliage for animal feed began with the late Dr. John Keays who went to Russia on a scientific exchange program several years ago. He found that the Russians were producing and using much more foliage than we were in North America. While he was there he gathered as much information as he could on their use of foliage. As a result of this, we have become involved in a research program examining the use of foliage for animal feed. Before I go into that, I will cover some of the background of what Dr. Keays found in Russia.

The Russians harvest what they call commercial foliage, which includes in it small branches, twigs (their definition was up to 6mm in diameter), and shoots as well as the needles, leaves, etc. He found that the Russians were doing three main things with it; they were producing a paste (chlorophyll-carotine paste) which they were producing from the foliage by extraction with petroleum ether. The yields of this paste are only about 4% of the weight of foliage input. Another product they were producing was essential oils through a process of steam distillation. Here the yields were 1 or 2% of the original foliage weights. The third product was just called "muka" and constituted the main item. This was basically foliage ground up and dried. The Russians were using this as an animal fodder vitamin supplement. "Muka" is the Russian word for flour.

The Russians made a number of claims for this material. They were feeding it to poultry and cattle and other livestock. They made claims of faster and greater growth, improved reproduction abilities, healthier animals, increased milk yields, and improved egg production. Current production of this muka is in the order of 100,000 metric tons per year in the USSR. If we look at the organic and inorganic contents of muka, we find some of the things that the Russians were interested in. The carotene was of considerable interest to them; e.g. spruce, 140 parts per million (ppm); birch, 330 ppm, versus lucerne or alfalfa at 170. Protein content is 9 and 8% for these two species versus 19% for alfalfa. That is reasonably good protein content. There is a slightly higher cellulose content for spruce versus lucerne, which means it has more roughage value. If we look at some of the inorganic constituents, total ash content, 4% for spruce and birch, versus 6% for alfalfa which is not too bad. Tree foliage was reported to be high in cobalt and manganese particularly. These were some of the things the Russians were interested in and which they found useful in their feed products.

Dr. Keays came back to Canada with this and other information on the amount of muka that animals would eat when fed to acceptance levels. He applied these figures world-wide to livestock populations for cattle, sheep and chickens and he came up with a potential muka market of 480,000,000 metric tons per year. If we look at the United States, it comprises roughly 10% of the world market, so you would have requirement for about 48,000,000 metric tons. If you wanted to go a little further to Canada, it would be about 10% of that again.

Examining foliage availability, Dr. Keays went through some calculations dealing with total annual timber cut of 4,000,000,000 cubic metres and estimates of foliage yields from various biomass studies to estimate total commercial foliage. He felt that perhaps half of it might be recoverable, for an availability of perhaps 160,000,000 tons. This compares with the potential market worldwide for 480,000,000 metric tons. At this point, he felt that a foliage research program looked worthwhile and we should pursue it further. As a result, we have become involved in some analyses and feeding trials related to the use of foliage for animal feed.

One of the problems with the Russian information is that nowhere in the literature that we

had available to us could we find out what the standard Russian feed was for their animals. For example, at a recommended dosage of 5% pine muka for cattle, they were claiming 20% weight increase and less susceptibility to disease, but there is no information on what this was relative to – a 20% increase over what? There were some questions left open here and feeding trials were necessary to find the answers. As a result of this, we got involved in our foliage project.

The first thing you get involved with in looking at foliage is how much is there and how do we get it into the manufacturing plant? Jim McIntosh and James Dobie have been doing a few studies on foliage yields. In one of these studies, spruce foliage constituted about 8% dry weight of a full tree and pine foliage made up 2½% of the total dry weight when delivering tree lengths with foliage to the mills. A lot of the foliage gets broken off in the process, but it's the easiest place to collect it. In this study, which was in Alberta, all logs were loaded butt first in the truck,as is commonly practiced by the firm co-operating in this study. If the logs were without branches and foliage, the load would just taper down towards the back of the truck. In this case, the foliage doesn't take up more space in the truck, so it doesn't cost any more to bring it in. An added bonus which the forestry people noticed is that a supply of cones was available right at the mill, which substantially reduced their cone collection costs for seeds for replanting purposes.

Another major question is what, if any, components of foliage would be useful in a feed product, and how do animals respond to it? George Barton, a WFPL chemist, has been involved in analyzing nutrient contents in foliage from two species in particular, lodgepole pine and white spruce. We felt that these would be relatively available throughout western Canada. We are looking at growth sites and how this affects mineral and vitamin content. The Russians were very concerned with how long they could store the material before it started to lose its value as a feed product. Hence, this was incorporated into our study as well. There was a question of whether summer or winter harvest had any affect on nutrient content. So we started to examine some of these factors.

Studies with white spruce and lodgepole pine haven't shown any effect of growth site. There was no difference in the nutrient content of the foliage from one site to another. It is possible that we didn't have great enough range in site quality to show such effects. The organic nutrient constituents that were found between summer and winter for spruce and pine are shown in Table 3. There is in the order of 6% protein in spruce and pine foliage. Total digestible nutrients ranges from 55 to 57%, equivalent to that found in medium-grade hay. There isn't much difference between summer and winter. This was one of the conclusions that we arrived at. The pine seems to have a little more of some nutrients than the spruce.

Examining the inorganic nutrient constituents (Table 4) we seem to have a little more calcium than the Russians had, less phosphorus, and much less magnesium. There is very little difference between summer and winter. There is a lot of natural variation in nutrient content between one individual and another, hence, much of the difference between figures in the table aren't statistically significant. Another factor we studied was storage time and its effect on nutrient content. For spruce in winter storage, we can see in Table 5 the carotene content appears to be increasing. However, this can't happen and the differences are due to the natural variability in the samples that were tested. Protein content remains relatively constant. George Barton concluded from this winter-cut material that there would be no trouble storing it for about a two-month period, and with the summer-cut material, there would be no problem storing it for one month, perhaps longer.

The second phase of this study involved animal feeding trials. These have been done in conjunction with the Department of Agriculture research station at Agassiz, B.C. The first trial was carried out using pure needles with the small twigs and branches separated out. Chickens were fed various amounts of foliage from 10% to 30% in their diets.The results indicated that there were no toxic effects – it didn't kill the chickens. On the other hand, they gained significantly less weight with the foliage added to the feed than they would have gained on the standard feed. So we do not see much benefit there. The only possible use might be

in areas where there is insufficient chicken feed or it costs too much to bring it in. This chicken feeding trial has been completed.

The next phase is just getting started and consists of feeding trials with sheep. There is quite a difference between the digestive systems of sheep and chickens. Sheep are ruminants and are capable of using some of the fibre content in the foliage, unlike chicknes which just cannot utilize this material at all. The feeding trials will be starting this fall. This, again, will be done by the Department of Agriculture with us supplying the feed material. In this case, we will be using commercial foliage which includes the small twigs and shoots, etc. So that is where out studies stand right now.

The question has been raised of using bark as a feed. I think the things that apply to wood also apply to bark to a large extent. As soon as you get into coniferous species, you get into problems, but with aspen there have been some tests with bark. The results have been somewhat conflicting. The researchers at the University of Saskatchewan included some bark in their last feeding trials and didn't get good results. A problem that has emerged is related to the methods they have been using to determine digestibilities of both wood and bark. Various people have been using different methods and there are some conflicting results that have not been resolved. This is one of the reasons why the Department of Agriculture is still doing tests. They have even come up with results that do not substantiate what the producer of the product (Stake Technology) claims is the digestibility of the material. The last set of tests at the University of Saskatchewan produced quite different results from the first set of tests they did on digestibility levels. Digestibilities of steamed aspen wood were acceptable in the first tests, but much lower in the last tests. In theory the bark should be just as good as the wood, and there have been some studies to show that. Professor Goodrich at the University of Minnesota put aspen bark in a silo along with other ingredients and obtained what he claimed was quite an acceptable silage product. He plotted out what the relative price of hay would have to be to make this bark silage profitable. I believe he came out with hay prices anywhere from $60 a ton up to make it worthwhile using this bark silage. So that was one study done by an agriculturalist which used aspen bark as an acceptable feed.

TABLE 1

DIGESTIBILITY OF WOOD

LODGEPOLE PINE	0%	RED ALDER	2%
WESTERN LARCH	3%	WHITE BIRCH	8%
DOUGLAS-FIR	5%	TREMBLING ASPEN	33%

TABLE 2

ECONOMICS - 80 TPD

PROCESSING COST		$18.38
UREA		4.00
WOOD		21.00
	TOTAL	$43.38

TABLE 3

AVERAGE ORGANIC NUTRIENT CONSTITUENTS

	SUMMER		WINTER	
	SPRUCE	PINE	SPRUCE	PINE
PROTEIN (%)	5.9	6.3	5.9	6.8
CAROTENE (MG/KG)	49	69	56	78
CHLOROPHYLL (")	859	1109	921	1283
ESSENTIAL OILS (%)	0.54	0.54	0.69	0.76
ACID DET. FIBRE (%)	34.1	36.3	34.8	37.9
TOT. DIG. NUT. (%)	57.3	55.8	57.2	54.7

TABLE 4

AVERAGE INORGANIC NUTRIENT CONSTITUENTS

	SUMMER		WINTER		RUSSIAN
	SPRUCE	PINE	SPRUCE	PINE	SPRUCE MUKA
CALCIUM (%)	0.91	0.39	0.90	0.32	0.7
PHOSPHORUS (%)	0.10	0.06	0.09	0.08	0.2
MAGNESIUM (%)	0.06	0.10	0.03	0.08	0.6
COPPER (PPM)	4.0	2.7	3.5	4	6
MANGANESE (PPM)	769	704	1045	759	292
ZINC (PPM)	38	43	42	43	32

TABLE 5

EFFECT OF STORAGE TIME ON NUTRIENT CONTENT

SPRUCE - WINTER

TIME DAYS	CAROTENE (mg/kg)	PROTEIN (%)	CHLOROPHYLL (mg/kg)	ESSENTIAL OIL (%)
0	69	5.9	952	0.45
7	72	5.7	1257	
21	71	5.0	1122	
35	76	6.2	1138	
49	79	5.6	1288	0.40

Wood Preservation

J.N.R. Ruddick

Introduction

This discussion of wood preservation will be divided into three broad areas. Firstly, through a brief study of elected decay problems encountered by the staff of the Biodeterioration and Protection Department, Western Forest Products Laboratory (WFPL), the need to preserve wood will be discussed. Having identified that there is a need to protect wood, methods of providing this protection against biodeterioration will be considered. Finally some indications of recent trends in wood preservation, including the types of commodities currently being treated, will conclude the presentation.

Examples of Decay Problems

One area where treated wood must be considered essential is in the construction of flat roof systems, since they will ultimately fail and allow the supporting wood components to become wet. Provided that the leakage of water is immediately obvious, the problem can be quickly remedied. However, as is usually the case, the installation of false ceilings, etc., frequently hide the fact that the roof is leaking. In a typical case encountered at the University of British Columbia, the failure of a flat roof membrane provided dramatic evidence of the problem. When the roofing material was finally removed for inspection, the plywood was extensively decayed (Figure 1), as were the top two laminations in the glued-laminated beams which supported the roof (Figure 2). Other roof components had been extensively decayed also and had to be replaced. The building was approximately four years old.

Another problem relating to the use of "glulam" beams concerns their frequent incorporation by architects, into structures where they project beyond the exterior of the structure. Since they are not usually preservative treated, they will decay. This decay is often accelerated by placing a poorly designed supportive metal "shoe" at the base of the glulam beam. This merely serves to trap the water, and maintain a plentiful supply of moisture for the fungi attacking the wood (Figure 3). Poor design of structures is a major contributing factor to the incidence of decay in wood structures.

In B.C. one can find many picturesque wharfs in which the supporting piles were pressure treated (usually with creosote), placed into position and were then cut to their final length, thereby exposing untreated heartwood at the sawn surface. Naturally, this unprotected wood decays with time (Figure 4) providing excellent photographic subjects, but limiting the useful life of the pile. With the use of an appropriate pile cap, the maximum advantage in using treated wood could be gained. Even the decking itself can be pressure treated. In a recent study undertaken by the WFPL, it was shown that after ten years, treated Douglas-fir decking remained in excellent condition, whereas untreated material in the same time developed extensive decay and had to be replaced.

Fenceposts are another commodity that is very familiar to most people. An untreated fencepost will rot at the groundline (Figure 5). With the increased cost of Canadian durable woods, and the resultant increase in use of non-durable wood spec-

ies, this failure of untreated fenceposts will be much more rapid.

Another decay problem, which is particularly relevant to the current housing practices, concerns the effect of condensation on window joinery (Figure 6). Because of our increased awareness of energy wastage, houses (and other buildings) are being sealed up much more effectively than previously, with the result that condensation problems are much more frequent. Since the source of moisture is of no concern to decay fungi, the incidence of rot in wooden window joinery has increased considerably. Although paint will provide protection by shedding rain water, the integrity of the paint film will usually be broken after six months of service due to the movement of the wood as it alternately becomes wet and dry. When this happens, the paint film can actually accelerate the decay since once the wood is wet, the paint film will slow down the loss of moisture due to evaporation from the wood surface. Of course, through the use of preservative treated wood, this decay problem would be eliminated. It can be seen from these few examples, that the problems associated with biodeterioration of wood are very varied. However, the *solution* to these problems is usually constant, and that is *to use preservative treated wood.*

Important Factors to Consider in Wood Protection

Before describing in detail the wood preservation processes, it would be helpful to identify some of the topics which are important in wood protection, and to indicate those which will not be discussed in this presentation.

When trees are freshly cut, the moisture content of the wood is very high, particularly that of the sapwood. Thus, when timbers are cut from these "green" logs they are susceptible to degradation by mould and staining fungi. Immediate kiln drying of the material would eliminate the problem, but this is not always feasible. The simplest method of providing short-term protection is by applying a wood protecting chemical to the freshly sawn timber. This treatment will not, however, confer any long-term protection against decay and insect attack when the wood is in service. Further, since mould and staining fungi tend to attack the carbohydrate free sugar rather than the cellulose and lignin, they do not cause significant strength losses (Figure 7). Therefore, this aspect of wood protection will not be discussed here, and the reader is referred to other studies for this information [1, 2]. Similarly, protection of wood against fire will not be discussed. As far as the problems relating to biodeterioration are concerned, no specific attention will be given to insect attack on wood, although the preservative treatments described will usually confer protection against carpenter ant and termite attack.

The major emphasis of this discussion will be in protecting wood against decay caused by white, brown and soft rot fungi. While the damage caused by the first two fungal types are well known, it is only relatively recently that an awareness of the problems relating to soft rot attack has developed. This is particularly true in Australia where CCA treated hardwood utility poles began to fail prematurely in service due to soft rot attack [3]. Thus, it is possible that the prevention of soft rot attack may be more difficult than the prevention of decay caused by white and brown rot fungi. White rot fungi attack both cellulose and lignin, whereas brown rot fungi tend to attack only the cellulose. It can be seen quite clearly that by attacking these wood components the fungi are going to cause a rapid strength loss.

What does a fungus need to grow? It basically requires the same four elements that support animal life: an adequate supply of air or oxygen, an adequate supply of moisture, a suitable temperature (i.e. if it gets too cold, growth may be arrested; if it gets too hot, growth may be halted or the organism may be killed), and a suitable source of food, which, in this case, is the wood (Figure 8). If any of these four elements is removed, the growth of the fungus will be stopped. Thus, if one kiln dries the material, then the factor of moisture is eliminated. Of course, this will not provide permanent protection, since, if the wood becomes wet in service, then obviously this condition has become reinstated and fungal attack can take place.

Wood itself is not a simple homogeneous medium. It is composed of cell structures with

voids or cavities, and inter-connecting chambers (Figure 9). The cell walls are composed of cellulose, hemicellulose and lignin. In a freshly cut tree, the cell cavities are filled with sap (i.e. water and chemicals). Upon drying, water is first removed from within these cavities. Further drying will result in the loss of moisture from the cell wall. This will take place when the moisture content of the wood is reduced to below the fibre saturation point. In preservation, in order that chemical solution will penetrate the wood, it is obviously essential to first remove the moisture that is contained within the cell cavities. Thus, drying of the wood is a very necessary initial step in wood preservation, and adequate drying is essential for efficient penetration of the wood preservative.

Wood Protection Processes

In considering the commercial processes used to impregnate wood with preservative, there are three main types. They are:

(a) the full cell process;
(b) the empty cell process;
(both of which employ pressure to force the solution into the wood), and
(c) the thermal process.

In the *full-cell process*, the material to be treated is placed inside the retort (a large cylinder closed at one end and with a door at the other), and the door closed. The retort is then evacuated for about 30 minutes at 20 inches of mercury, after which preservative solution is introduced into the retort and pressure applied. For most commodities the applied pressure is in the range of 100 to 150 lb/in.^{2}. During this pressure period, the solution is forced into the wood. In treating timbers, the pressure is maintained until the wood has taken up sufficient chemical, based on the solution concentration. In some instances, this may require treating the wood until no further uptake of solution is observed, when the material is said to have been "treated to refusal". Finally, following this pressure period, the solution is removed from the retort and a short final vacuum is applied to remove excess chemical from the wood surface (Figure 10).

The *empty-cell process* is similar to the full cell process in that the only major difference arises during the initial vacuum stage. In an empty-cell process, there is no initial vacuum. Indeed, in one type of empty-cell process (Reuping), a small positive pressure is applied prior to the introduction of preservative into the retort. However in the more common empty-cell process (Lowry) the solution is pumped into the retort immediately following the loading of the timber.

The *thermal process* which is a pseudo-pressure process since the applied pressure is only one atmosphere, is used mainly for the preservation of poles and fenceposts with oilborne preservatives. During the treatment, the pole is placed into a hot oil bath causing the air within the wood cells to expand and be lost from the wood. The pole is then placed in a cold bath of preservative solution and the air remaining in the wood contracts, creating a vacuum which draws the preservative into the wood. The thermal process is of minor commercial importance when compared to the treatment of forest products by the full-cell and empty-cell processes.

The Principal Wood Preservatives Currently in Use

The formulations used in wood preservation may be conveniently divided into two basic types; those which are organic based and dissolved in an oil solvent (oilborne), and those which are dissolved in an aqueous solvent (waterborne). The two principal oilborne preservatives are creosote (and creosote containing mixtures), and pentachlorophenol (PCP). Creosote is a coal tar product. As such, its supply is likely to be influenced by recent trends in the gasification of coal. Creosote is not a simple chemical formulation, but is instead composed of many organic compounds, several of which have not been identified. Therefore, laboratory quality control procedures for both the preservative and the treated wood have not been developed in the usual analytical manner. For the preservative solution, the quality control procedures have been based entirely upon the determination of the physical properties of a mixture of unknown compounds. However, despite the rapid growth in the use of other preservatives, over 50% of the total volume of preservative treated prod-

ucts in the USA in 1976 were treated with either creosote or creosote containing mixtures (4).

The second oilborne preservative which is of major importance to the wood preservation industry is pentachlorophenol (PCP). This is a chlorinated aromatic chemical, available either as a crystalline compound or as a compressed solid. When used by the preservation industry, it is usually dissolved in a light petroleum solvent. However, in one special type of process it is dissolved in a liquified gas to which a co-solvent has also been added to improve the solubility of the PCP. This process is frequently referred to as LPG process (i.e. liquified petroleum gas), and it has the advantage that following treatment, the solvent may be readily removed to leave a clean "dry" product. However, the majority of PCP preservation which takes place uses the conventional "PCP in oil" system. In 1976, about 27% of the total volume of treated products in the USA were treated with PCP preservatives (4).

With the general increase in the cost of oil products likely to continue, one may anticipate that a gradual reduction in the use of oilborne preservatives will take place for those commodities for which the waterborne preservatives are an acceptable alternative. Except in special circumstances when extra heavy chemical retentions are required, treatment with oilborne preservatives is performed using the empty-cell process.

Considering now the waterborne preservative, there are again two main formulations in use. They are chromated copper arsenate (CCA) and ammoniacal copper arsenate (ACA). CCA usually contains copper as copper oxide or carbonate, chromium as chromic acid and arsenic as arsenic pentoxide. Since the aqueous solution containing these components is strongly acid, a clear solution is obtained with no precipitation. However, once the solution enters the wood a complex series of chemical reactions take place which result in all the components becoming well fixed. During this fixation process the treated wood which at first is quite green, changes to a green-brown colour. Although several CCA formulations exist, the trend in the wood preservation industry is towards the formulation referred to as CCA-type C, which contains more chromium than arsenic on a weight basis (i.e. CuO 18.5%; CrO_3 47.5%; As_2O_5 34%).

The other waterborne chemical which is in most common use is ACA. This preservative employs ammonium hydroxide as the solvent. The base mix contains copper, usually in the form of the oxide or the basic carbonate, and arsenic trioxide. In preparing a solution of ACA, the base mix is stirred in ammonium hydroxide, while at the same time air is passed through the solution. The resulting deep blue solution contains a complex copper-ammonium salt in which the arsenic has undergone a chemical change from the original trivalent state in the trioxide to the pentavalent form as the pentoxide. Following impregnation of the chemical into wood, the copper-ammonium complex is broken down causing the copper arsenate to be precipitated. In an ACA solution, the ratio of the copper (expressed as copper oxide) to arsenic (expressed as arsenic pentoxide) is 1:1.

In 1976, about 18% of the total volume of treated products in the USA were treated with waterborne preservatives.

The Role of Incising in Improving the Quality of the Preservative Treatment

When roundwood or timbers are pressure impregnated with preservative it is unusual for the chemical to penetrate the material completely. Instead, it is the aim of the wood treater to provide the commodity with a shell of treated wood which completely encloses the untreated core (Figure 11). The continual protection of this untreated wood is dependent upon the ability to maintain the integrity of this shell of treated wood, which in turn must have received sufficient chemical to withstand fungal attack. The adequate seasoning of the wood prior to preservative treatment is *essential* , since during the drying of wood to moisture contents below 20%, the loss of moisture from the cell walls causes a significant reduction in its volume. This results in the fibre separation and fracture, known as checks. These checks can penetrate quite deeply into the wood, and if they were formed after preservative treatment would result in a break in the shell of treated wood(Figure 11), through which subsequent fungal attack of the un-

treated wood could take place. For the same reason all cutting, boring, etc., of the wood should, whenever possible, be carried out prior to treatment with preservative. If this is not possible, the cut surface should be liberally coated with a concentrated preservative solution to restore the integrity of the treated shell.

For roundwood with a substantial width of sapwood, the creation of this shell of treated wood is relatively simple, since sapwood when dried is usually easily penetrated by preservative. However, in timbers composed of heartwood or in roundwood in which the band of sapwood is very narrow, maintaining the integrity of this outer protective shell, once the material is in service, is almost impossible. The reason for this is that only minor worsening of any checks is necessary before they penetrate through the shell, and expose untreated wood. To overcome this problem, advantage is taken of the fact that longitudinal penetration of preservative in wood is much easier than either tangential or radial penetration. Incisions about 0.5 in. in length are made in the wood. These incisions have a depth equal to the required depth of penetration of the preservative, and are cut parallel to the longitudinal direction to minimize strength losses in the wood (Figure 12). As a result of this process, called incising, during the subsequent pressure treatment, chemical is delivered immediately to the required depth from where it may penetrate the wood in the longitudinal direction. By arranging the incisions in a staggered pattern, it is possible to overcome the limited tangential penetration of the preservative in the wood, and thus create a substantial band of treated wood even when the wood is somewhat difficult to treat. An additional benefit provided by incising is that it tends to encourage the formation of several minor checks rather than one major check.

Present and Future Directions in Wood Preservation

It is obvious to anyone in Canada that changes have taken place in the last few years with respect to the preservation of wood in service. For example, there has been an acceptance by the hydro companies of utility poles treated with the waterborne preservatives (CCA and ACA). As a result of the high cost of repairing decayed structures, much more consideration is given to the use of pressure preservative treated wood in new building construction. Two building components which are frequently treated with either CCA or ACA are siding (Figure 13) and shingles. However, even the service life of municipal furniture (Figure 14), pole buildings, bridge decking, fenceposts and adventure playgrounds for children (Figure 15) can be substantially increased by preservative treatment. One of the major recent developments in the wood preservation industry is the use of pressure treated wood for house foundations (Figure 16). This preserved wood foundation (PWF) system has been used to advantage in several provinces in Canada. It is of particular value in those regions where the use of concrete is not convenient. The WFPL is currently very active in monitoring the performance of selected houses which incorporate a preserved wood foundation, as well as investigating methods of improving the system.

Other research undertaken by the Biodeterioration and Protection Department, WFPL, include the treatability of plywood, nondestructive methods of detecting decay, the development of new wood preservatives, the laboratory and field evaluations or preservatives, the treatability of alternative wood species [5], the corrosion of fastener caused by the use of treated wood, the improvement in the service life of shingles and shakes by preservative treatment [6], and reviews of selected topics [7]. A report describing the research carried out by the WFPL is published regularly [8]. The WFPL frequently provides independent test data which can be used to develop and improve the Canadian standard for the preservative treatment of wood.

Finally, it is well to remind ourselves that in considering the energy requirements to produce building construction materials, the energy cost of producing treated timber is well below that of producing cement, steel or aluminum (Figure 17), and Canada can ill afford to waste its natural resources.

Acknowledgement

The author is pleased to acknowledge the assistance of Dr. R.S. Smith in supplying Figures 7 and 8.

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Fig. 1 Inspection of decayed plywood from a flat roof.

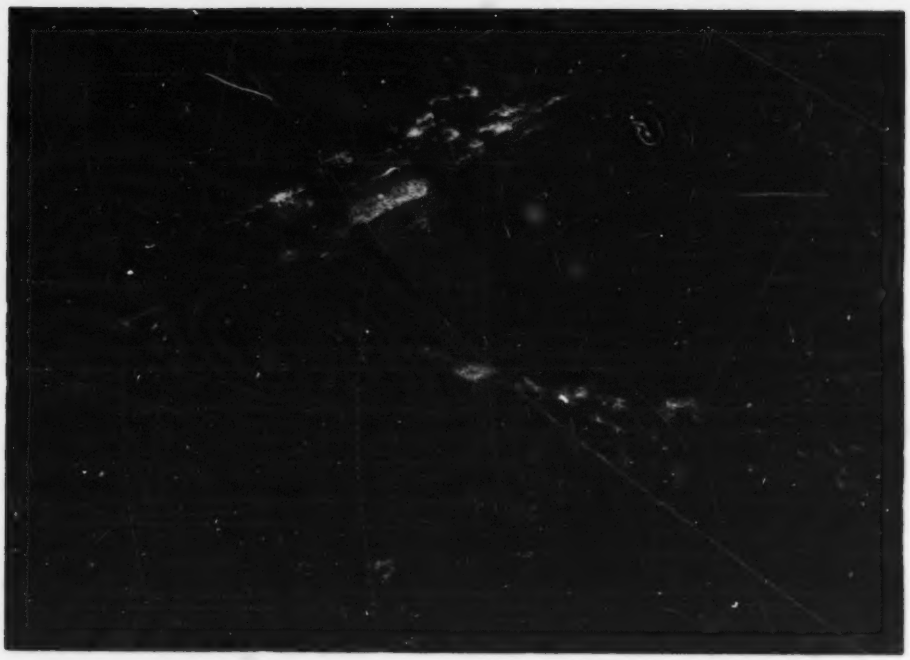


Fig. 2. Extensive decay in a laminated beam roof component.

Fig. 3. Decay is frequently accelerated by poor design. This metal shoe trapped rainwater and, by maintaining a high moisture content in the glue laminated beam, encouraged decay.

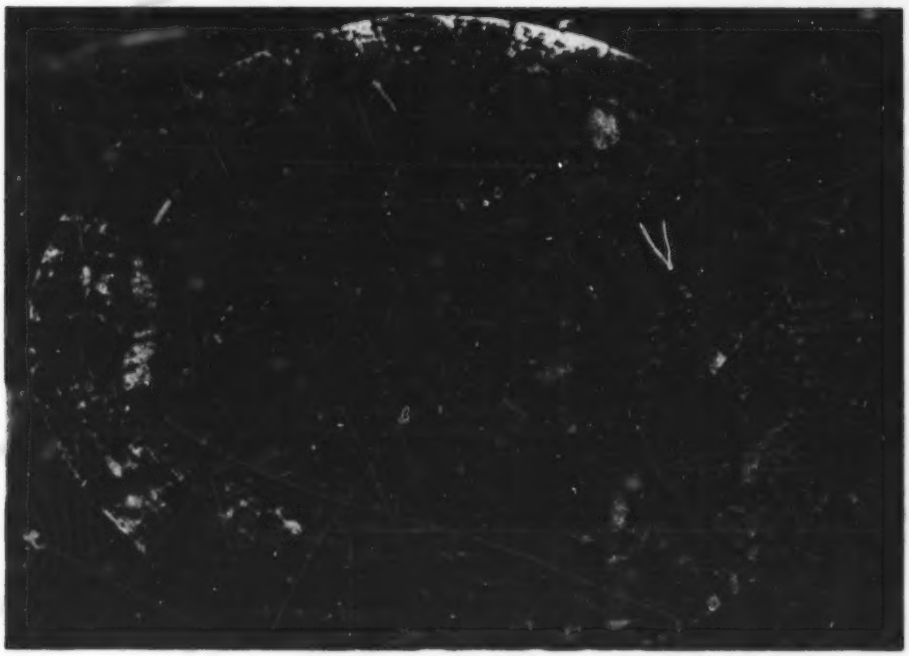


Fig. 4. Failure to cap this treated marine pile following the final cutting to length resulted in decay of the untreated heartwood.

Fig. 5. Decay in a western red cedar fencepost after 12 years of service. Fungal attack is greatest near to the groundline.

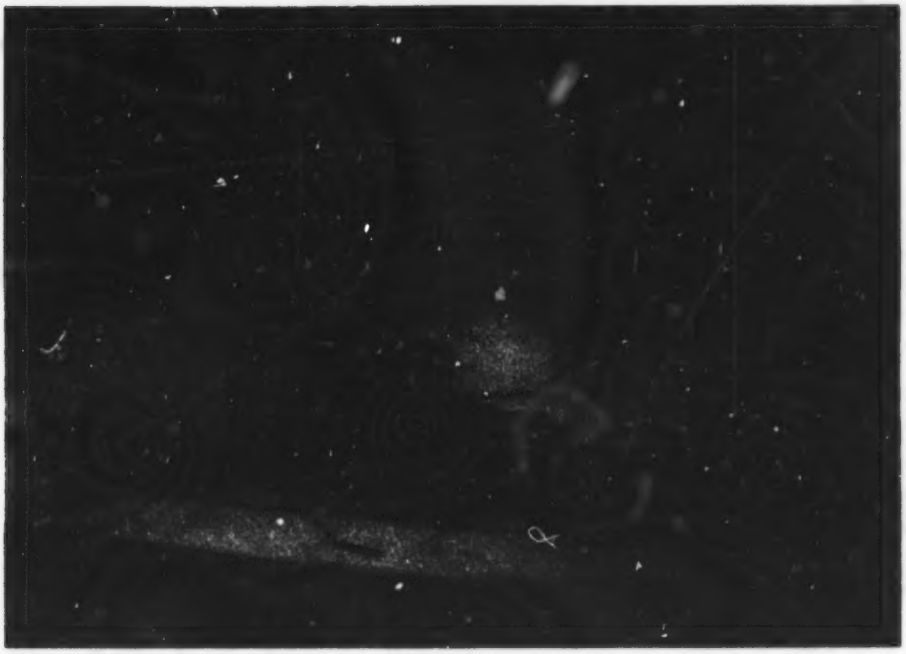


Fig. 6. Decay, established in this untreated window sash by failure of the putty seal at the joint, was accelerated by condensation forming on the inside of the window.

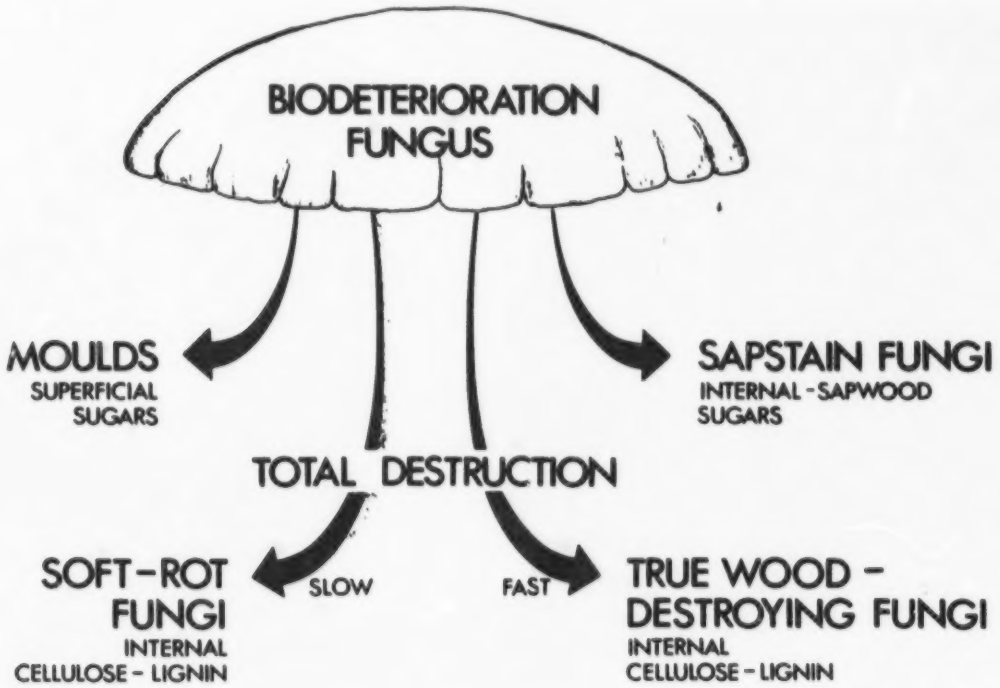


Fig. 7. Diagram illustrating how the four major groups of wood inhabiting fungi attack wood.

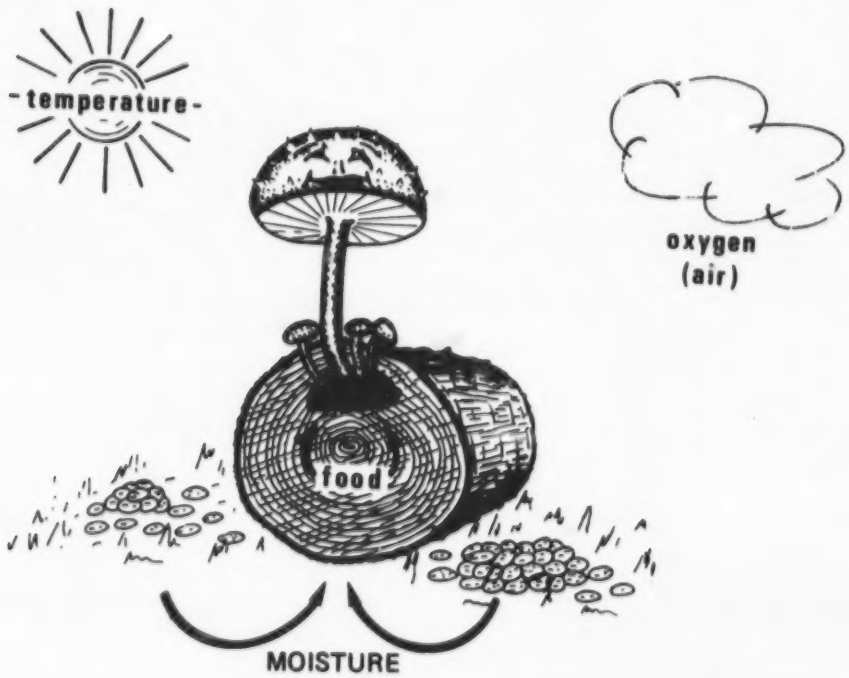


Fig. 8. The four basic requirements for good fungal growth.

Fig. 9. Figure showing the cellular nature of wood.

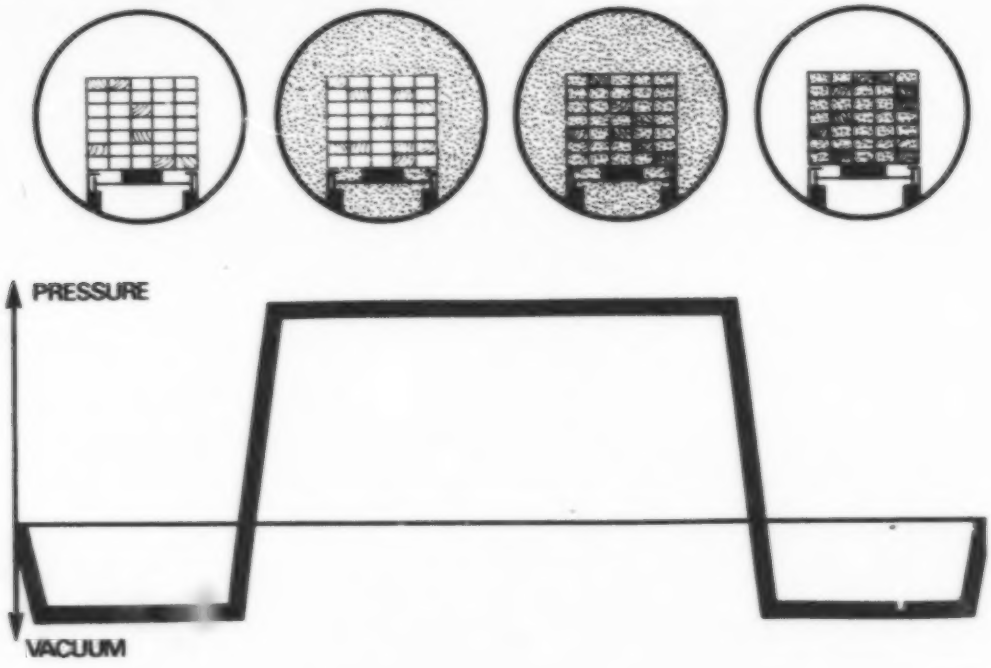
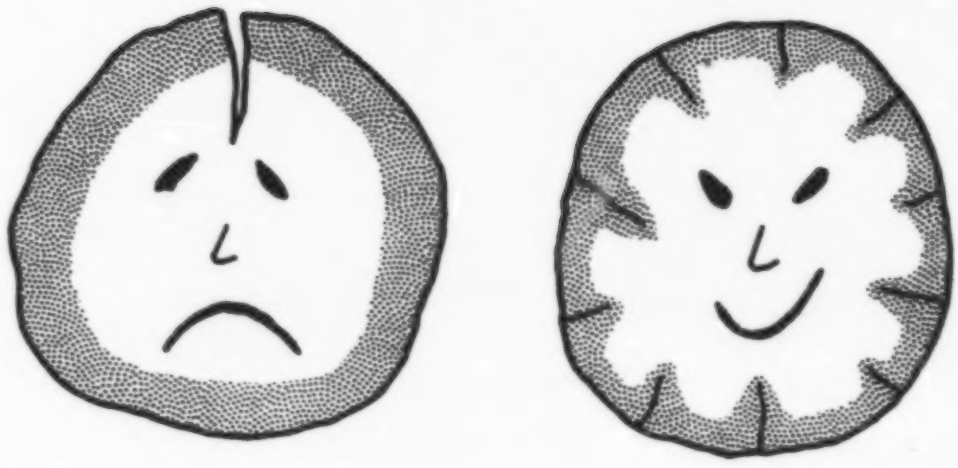


Fig. 10. The full-cell process is used for the pressure treatment of wood with waterborne preservatives.



A. Wood too wet before treatment; subsequent checking has passed through treated shell and exposed untreated wood.

B. Wood properly dried prior to treatment; see that checks are well treated.

Fig. 11. Adequate drying of wood prior to preservative treatment is essential.

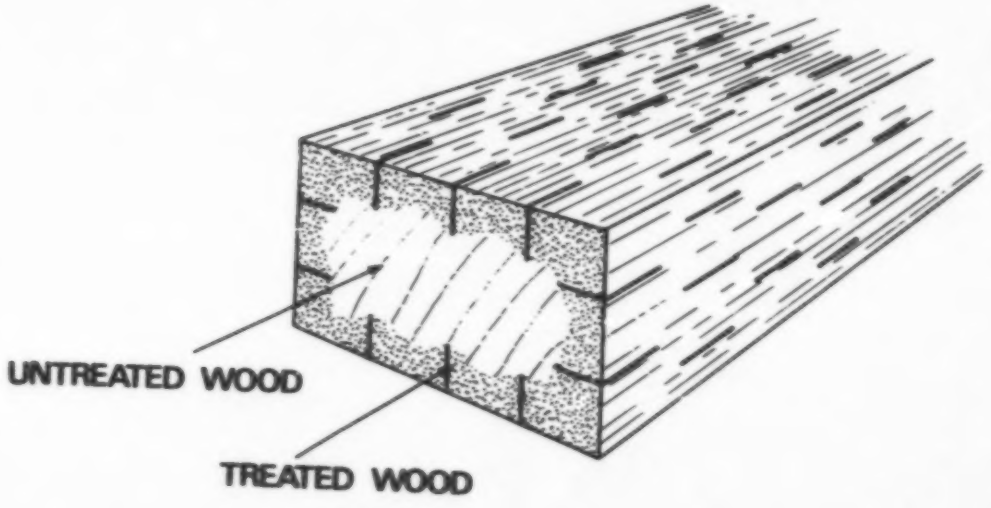


Fig. 12. For wood species not easily penetrated, incising enables a uniform shell of treated wood to be created which protects the untreated core.

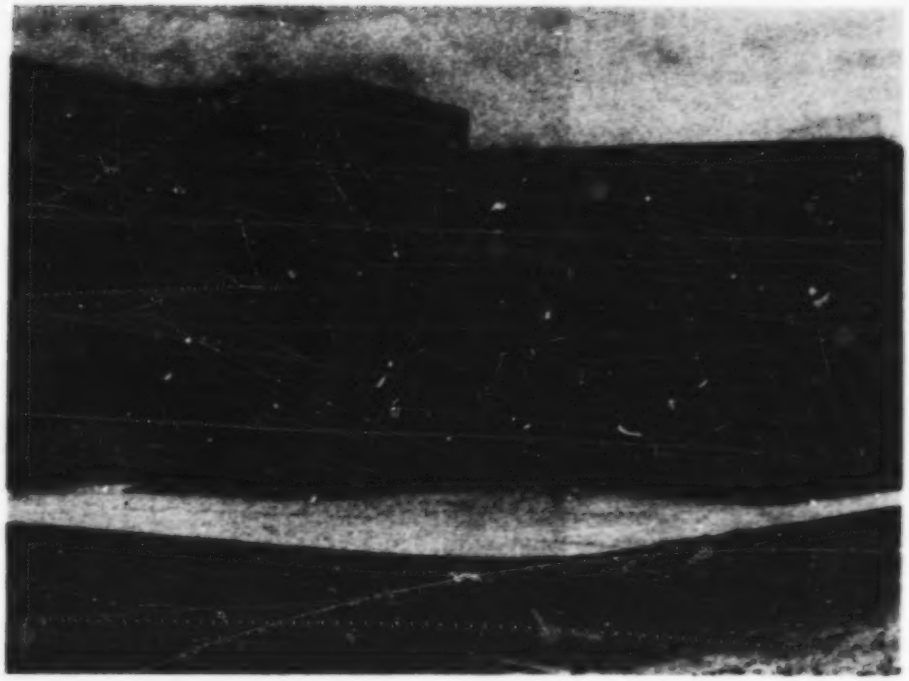


Fig. 13. Siding can be pressure preservative treated to prolong its service life, while the natural colour of the treated product may also be used as the final finish.

Fig. 14. The replacement costs of municipal signs, decorative structures, seats, etc., may be lowered through the use of preservative treated wood.

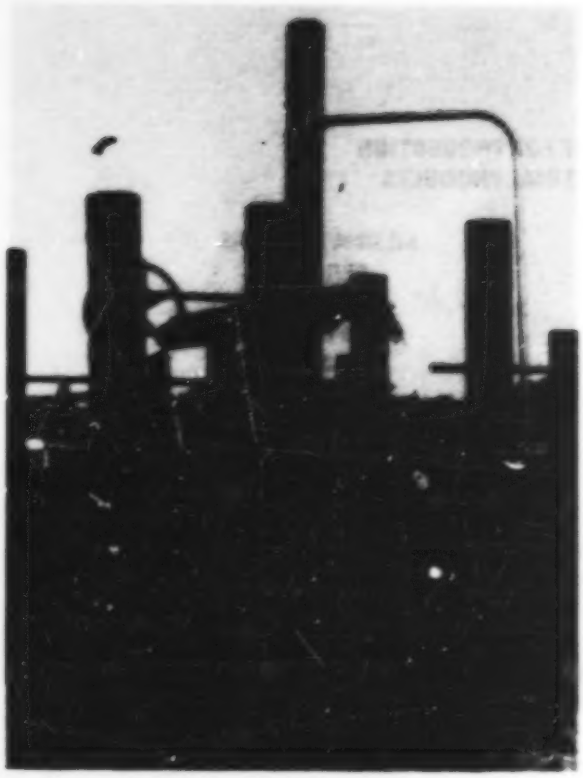


Fig. 15. Studies have shown that waterborne preservatives are well fixed in the wood and are, therefore, safe for use on such commodities as children's playground equipment.

Fig. 16. The introduction of the preserved-wood foundation system caused a major increase in the production of CCA and ACA treated plywood and lumber.

ENERGY REQUIREMENT FOR PRODUCTION OF SELECTED INDUSTRIAL PRODUCTS

PRODUCT	KILOWATT HOURS PER TON
ALUMINUM	[illegible]
STEEL	[illegible]
CEMENT	[illegible]
PLYWOOD	[illegible]
LUMBER	[illegible]
TREATED WOOD PRODUCTS	1,[illegible]

ECONOMIC, SOCIAL AND ENVIRONMENTAL BENEFITS FROM USE OF WOOD PRESERVATIVES. 1977. REPORT BY H.R. JOSEPHSON TO AWPI

Fig. 17 A comparison between the energy required to produce treated lumber and that used in producing other building materials.